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SEMINAR ON OFFSHORE OIL AND GAS PRODUCTION WASTES

Presentation Notes and Issues Raised at a Series of Seminars Held in St. John's, Halifax, Ottawa and Calgary

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SEMINAR ON OFFSHORE OIL AND GAS PRODUCTION WASTES *

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SUMMARY OF QUESTIONS AND ISSUES RAISED DURING SEMINAR DISCUSSION PERIOD

OFFSHORE OIL AND GAS PRODUCTION WASTE SEMINAR TOUR

A SUMMARY OF THE QUESTIONS AND ISSUES RAISED DURING THE DISCUSSION PERIOD

A. AT ST. JOHN'S

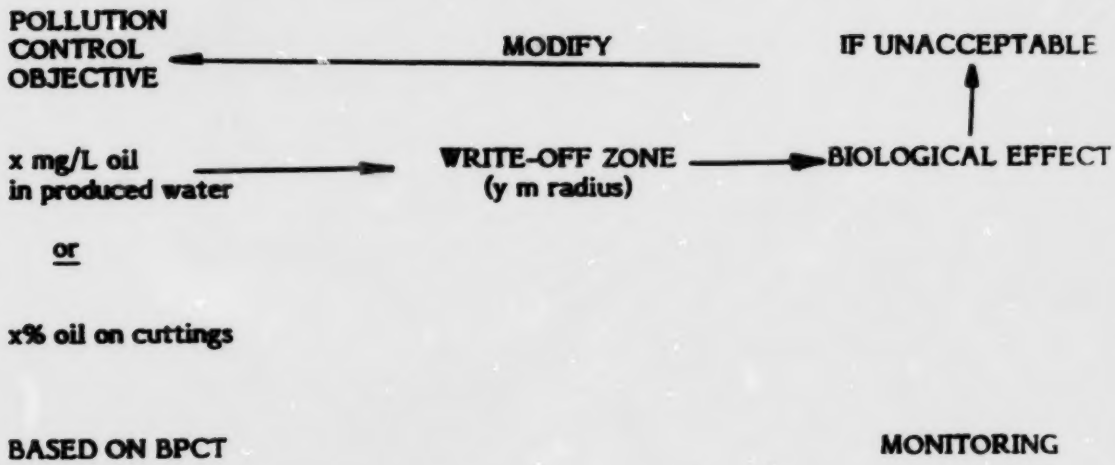
(1) A concern was raised about substituted nitrogen heterocycles in formation waters. These compounds tend to be very soluble in sea water; consequently, they can remain in the water column for long periods of time with the potential for adverse effects on water-column organisms. They are, as a class of compounds, difficult to isolate for analysis. Considering the expected amount of produced water to be discharged, the rate of dispersion on the Grand Banks and Scotian Shelf, the chance for any significant biological effect was considered remote. Yet, opinion still sided with "comfort" monitoring studies and even fish tainting studies on the Grand Banks.

(2) A suggestion was made to monitor for sulphur-containing heterocycles because of the observed tainting of fish caused by sulphur (heterocycles) in Japan. (Sulphur heterocycles are not discussed in the report: only sulphate in produced water is included. There have been, however, large discharges of sulphur in some Gulf of Mexico produced waters.)

(3) It may be possible to sample Canadian formation waters during exploration drill stem tests. However, contamination of the sample by drilling fluids and steel pipes would likely be a problem.

(4) Regulations are not able to address non-scientific issues related to offshore production. Open meetings, held by government agencies, can be used to address these perceived concerns.

(5) A useful model for the linking of standards set on the basis of BPCT and those set on the basis of environmental effect/marine environment quality is as follows:



(6) Concensus opinion agreed with the statement in the report that current technology is adequate for dealing with minor wastes. The key to success is good operating procedures.

B. AT HALIFAX

(1)
- When permitting individual operations offshore (exploration, development or production) under a general permit, must also consider "where" activities will or will not be allowed, not just that permit conditions are met.
- Must be able to account for important or sensitive marine environments in a given region when setting out general permit conditions (example of razor clams in Cook Inlet, Alaska).
- May want to be able to exclude activities from some highly sensitive areas.
- Therefore, site-specific/operation-specific permits are needed to accompany general permits.

(2) There was general agreement that the loading concept as the basis for regulation is a valid and preferred approach. The concept of "environmental space" was discussed. Because environmental space is finite in size, it can be used up. When this happens or is approached, a driving force for improvements to control technology is created. The improvements will aim to limit/eliminate further contaminant discharge.

Steps:

(i) start with industry using BPCT;

(ii) review loadings and scale of these loadings and probable effects;

(iii) if acceptable, then proceed;

(iv) if level of loading is unacceptable, improve the control technology or have operators buy environmental space.

(3) If loading, instead of concentrations, of contaminants is used as the basis for regulation, then the regulator must consider all sources of contamination not just those associated with offshore oil and gas production. In other words, given limited environmental space, how do

you regulate discharges from a number of differing sources? e.g.. produced water and pipeline discharges. Also, how do successive operators get regulated within a given region? How do they "share" the available environmental space?

(4) The setting of environmental controls at an appropriate level may be difficult, but must be technically justifiable. How do you decide an acceptable/unacceptable level of Hg in barite? What criteria do you use? (We suggest loading and considerations of biological availability.) One way is to reject those sources of barite which have Hg levels well above the range of most other sources. But other "political" factors such as Canada Benefit requirements may make it difficult to enforce a limit on Hg in barite, if, for instance, a Canadian or regional barite source were contaminated, but occurred in an economically depressed area.

(5) The general permit concept has implementation problems in Canada. What institutional/legislative arrangements do we have to develop permit conditions? The U.S. has the New Source Performance Standards and National Pollution Discharge Elimination System (NPDES) to develop permit conditions. But Canada has no means for conducting such long-term environmental analyses as are done to develop NPDES conditions. (However, EPS has been able to develop national "performance standards" in the case of petroleum refining and other industries.)

(6) Despite the many difficulties (to the industry) which result from imposing a "no-surface-sheen" requirement, as is done in the U.S., such a requirement does impose a high level of housekeeping/good practice on the operators.

(7) The concept of a "high impact" zone or "write-off" zone around an offshore platform was discussed in detail. There was no general agreement about what an acceptable degree of environmental damage would be.

C. AT OTTAWA

(1) Should regulations specify the control technology to be used by offshore operators? There was general agreement that this would be inappropriate.

(2) Should government fund the development of acceptable means of compliance (new control technology)? There was considerable debate on this topic, with no general agreement.

(3) The setting of standards on the basis of BPCT may stifle innovation by endorsing the status quo: industry invests large amounts of capital in a particular type of technology. It is then difficult for the industry to change the control technology so as to respond to environmental effects determined by monitoring.

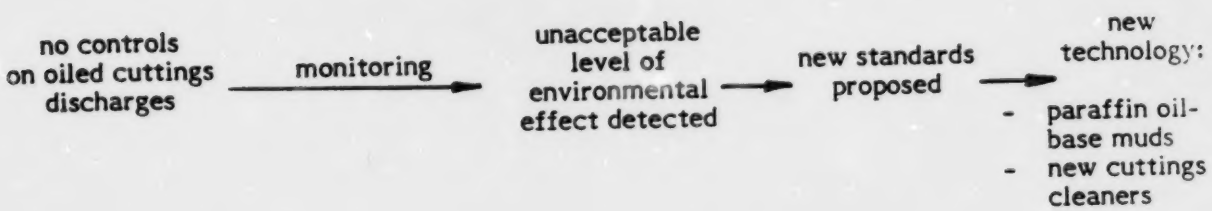
(4) As a general principle, new technology should continue to be developed to allow continued reductions in the amount of wastes/contaminants going into the environment. Therefore, innovation should be encouraged. (Again there was not general agreement). However, even if BPCT is set as A basis for controls, technology will not stagnate because industry has the incentive to strive for increased efficiency in treatment system operation (a decreased operating cost). There is also an incentive to increase oil recovery (separation) from produced water because the product has value.

(5) Whatever control technology chosen, a key factor in successful management/regulation of wastes is the recognition of certain operational realities and the practical limitations in dealing with them.

(6) Along with cost, it is important to take into account the reliability (not just oil removal efficiency) of incrementally better treatment plants. Breakdowns obviously result in no oil removal from waste streams; it is clearly preferable to employ a device slightly inferior in efficiency if it far out-performs (greater reliability) another device.

(7) Objectives (pollution control) set higher than existing standards can be used to foster a movement toward the use of new technology and more efficient treatment systems.

(8) How do you link BPCT to environmental quality? One answer is through monitoring. When monitoring identifies an environmental effect judged to be unacceptable, more stringent objectives or effluent standards would be set. The development of new technology would be encouraged if existing technology was inadequate. The use of oil-base mud systems in the North Sea is a good example.



(9) In the offshore, space is at a premium. Therefore, space constraints must be considered when setting standards which may require large treatment systems.

(10) How much work do we need to continue to do to determine the variability of environmental parameters on the East Coast? Hasn't sufficient work already been done? Besides the true variability of some/many processes, populations, etc. will never be known exactly.

(11) An important factor in determining appropriate regulatory controls is the effect of waste dispersal on the long-term restoration of the benthic environment to pre-development conditions. The long-standing waste disposal strategies of dispersal and confinement were discussed. That is, is it better to encourage dispersal of the waste over large areas so that recovery time is reduced? Or is it better to confine the waste to limit the effects to a very small area of the seabed but probably slow (or

eliminate) recovery? The common opinion was that both strategies have merits. The one employed at a specific time would depend on the details of each specific discharge situation i.e., type of waste, resources at risk, geographic setting, oceanographic conditions etc. Decisions then would be made on a case-by-case basis.

D. AT CALGARY

(1) Do we need to be concerned about aromatic hydrocarbon loadings in offshore areas resulting from production of oil and gas? Wouldn't refinery loadings be higher or at least of greater consequence because they are discharged into (relatively closed) coastal systems?

(2) The concept of loadings and chemical mass balance was well-received. The very important "dynamic" property of the mass balance approach was recognized and discussed.

(3) Who should develop production scenarios (many fields over time) and loading estimates to allow maximum cumulative loading to be determined and standards for regulation to be set?

(4) The proposed regulatory framework in the report was considered to be:

- philosophically a good approach
- ecologically good

but how do you apply it?

(5) Can BPCT and loading be used at the same time as the basis for setting standards? Are they not mutually exclusive? Or, is monitoring the link between the two?

(6) How do you set the boundaries in the ocean for the application of loadings as the basis for discharge limits? You do not have a well-defined watershed. However, it may be somewhat analogous to the airshed concept used in the U.S. (e.g., x kg aromatics allowable in discharges to y km^2 area of sea bottom)

(7) The simplest approach to regulation is a blanket standard based on BPCT. This must be applied in all offshore regions. Otherwise:

(i) government would have to negotiate with industry on a region-by-region basis, creating a large work load;

and (ii) pollution havens may be created (this was an Ottawa comment).

(8) The idea of a "write-off" zone was accepted as a sensible compromise between protecting the environment and the recognition of operational realities. The question is "How big should the zone be?" "What guidelines should be used to define it?"

(9) The application of "best operational techniques" is at least as important as the control technology used. (BPCT, in definition, does take into account operational practice.)

(10) One operational problem in applying the loading concept is that the volume of waste (particularly produced water) discharged with time is not often well known. In general, the producing characteristics of the formation will not be well known until the field is well into production. There are examples in the North Sea, for example, where water flows were much lower than had been expected (with oily water separators being overdesigned), and conversely where breakthrough of injection water occurred earlier than expected and resulted in much larger produced water volumes than had been anticipated (and designed for) early in the field life.

SLIDE PRESENTATIONS

SESSION 1

CONCLUSIONS AND POLICY IMPLICATIONS

TOPICS FOR SESSION 1

- ADEQUACY OF OFFSHORE PRODUCTION WASTE TECHNOLOGY
- SIGNIFICANT CHEMICAL CONSTITUENTS OF OFFSHORE PRODUCTION WASTES
- REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGES
- INFORMATION DEFICIENCIES AND RESEARCH NEEDS

ADEQUACY

OF

OFFSHORE PRODUCTION WASTE TREATMENT TECHNOLOGY

- Produced Water
- Water-base Drilling Fluids and Cuttings
- Diesel Oil-base Drilling Fluids and Cuttings
- Paraffin Oil-base Drilling Fluids and Cuttings
- Ballast Water
- Storage Displacement Water

ADEQUACY OF OFFSHORE PRODUCTION WASTE TREATMENT TECHNOLOGY

Produced Water

Treatment System	Adequacy
skim tank - gas flotation/ surface or subsurface disposal	• existing standards for total oil met under normal conditions (30 - 50 mg/L) • upset conditions cause 100% + increase in total oil • aromatic hydrocarbons partially removed
skim tank - skim pile/ subsurface disposal	• existing standards for total oil not met • prevents surface slick • partial backup in case of treatment system failure

ADEQUACY OF OFFSHORE PRODUCTION WASTE TREATMENT TECHNOLOGY

Water-Base Drilling Fluids and Cuttings

Treatment System	Adequacy
solids control system (screen, centrifuge) to separate fluid from cuttings cuttings discharge to sea continuously/surface or subsurface mud dumped to sea after use	• adequate in most offshore areas • sensitive offshore areas: - dilution - shunt to bottom - haul to shore

ADEQUACY OF OFFSHORE PRODUCTION WASTE TREATMENT TECHNOLOGY

Diesel Oil-Base Drilling Fluids and Cuttings

Treatment System	Adequacy
Current:	
diesel-oil or water/ surfactant cuttings washer	• not adequate/large amount of oil adheres to cuttings (25-30%)
State-of-the-Art:	
distillation, extraction or centrifugation	• adequate/oil reduced to 1-5% of cuttings weight
Fluids:	
all used muds hauled to shore	• adequate/no discharge

ADEQUACY OF OFFSHORE PRODUCTION WASTE TREATMENT TECHNOLOGY

Paraffin Oil-Base Drilling Fluids and Cuttings

Mud System	Adequacy
Current:	
standard paraffin oil system/no treatment	• considerable oil adheres to cuttings (15–20% aromatics)
State-of-the-Art:	
specialty paraffin oil system/3 shakers/ no cuttings cleaning	• adequate/considerable oil adheres to cuttings but aromatic content very low (< 1%)

ADEQUACY OF OFFSHORE PRODUCTION WASTE TREATMENT TECHNOLOGY

Ballast Water*

Treatment System	Adequacy
onshore:	
settling tank - gas flotation - settling pond	• total oil effectively removed • aromatics partially removed • segregation of process wastes from treatment system necessary
offshore:	
settling tank - plate coalescer	• total oil effectively removed • aromatics not removed

* Segregated ballast tankers will reduce ballast water treatment requirements.

ADEQUACY OF OFFSHORE PRODUCTION WASTE TREATMENT TECHNOLOGY

Storage Displacement Water

Treatment System	Adequacy
interface water through a plate coalescer	● adequate/ interface water contains little emulsified oil and aromatics

SIGNIFICANT CHEMICAL CONSTITUENTS

OF

OFFSHORE PRODUCTION WASTES

SIGNIFICANT CHEMICAL CONSTITUENTS IN OFFSHORE PRODUCTION WASTES

- HYDROCARBONS - AROMATIC COMPOUNDS
- PERSISTENT CHEMICALS
- METALS

SIGNIFICANT CHEMICAL CONSTITUENTS IN OFFSHORE PRODUCTION WASTES

HYDROCARBONS

CRUDE OIL

- PRODUCED WATER
  - total oil 40 mg/L
  - aromatic compounds 5-10 mg/L
- PRODUCED WATER TREATMENT PLANT UPSETS
  - total oil may be 2-4 times oil content of normal discharge
- BALLAST WATER
  - total oil 10 mg/L
  - aromatic hydrocarbons 5-10 mg/L
- STORAGE DISPLACEMENT WATER
  - total oil 10 mg/L max.

SIGNIFICANT CHEMICAL CONSTITUENTS IN OFFSHORE PRODUCTION WASTES

HYDROCARBONS

REFINED OILS

- SOURCES
  - oil-base mud system cuttings
  - water-base muds and cuttings
  - deck drainage
- DIESEL OIL
  - adheres to discharged cuttings from oil-base mud systems
  - approx. 100-300 tonnes per well
  - as spotting agent for water-base muds
- PARAFFIN OIL
  - adheres to discharged cuttings from paraffin oil-base mud systems
  - approx. 50-200 tonnes per well
- LUBRICATING, HYDRAULIC AND OTHER REFINED OILS
  - from deck drainage
  - very minor input if well managed

SIGNIFICANT CHEMICAL CONSTITUENTS IN OFFSHORE PRODUCTION WASTES

PERSISTENT CHEMICALS

- **SOURCES**
  - oil water treatment
    - produced water
    - ballast water
  - drilling fluids
  - well-completion fluids
  - oil and gas processing wastes
- **BIOCIDES**
  - aldehydes and quaternary amines
  - chlorinated hydrocarbons are prohibited
- **SURFACTANTS, DISPERSANTS, DETERGENTS**
  - used to wash decks, clean oiled cuttings, treat produced water and ballast water
  - include aromatics in some cases
- **CORROSION INHIBITORS, SCALE INHIBITORS**
  - organic chemicals
- **HALOGENATED HYDROCARBONS**
  - prohibited in adherence to London Dumping Convention

SIGNIFICANT CHEMICAL CONSTITUENTS IN OFFSHORE PRODUCTION WASTES

METALS

- SOURCES
  - drilling fluid components
    - barite
    - chrome-, ferrochrome lignosulphonate
  - produced water
    - low compared with drilling fluids
- LOADINGS
  - generally equal to or lower than natural loading rates for Canadian offshore regions (exception is loading of Cd, Pb on Scotian Shelf)
- TREATMENT TO REMOVE METALS FROM WASTES
  - generally impractical and unnecessary
  - alternative approaches
    - screening of mud products
    - low metal content mud additives
    - prohibition of certain mud additives
- MERCURY AND CADMIUM COMPOUNDS

REGULATORY FRAMEWORK

FOR

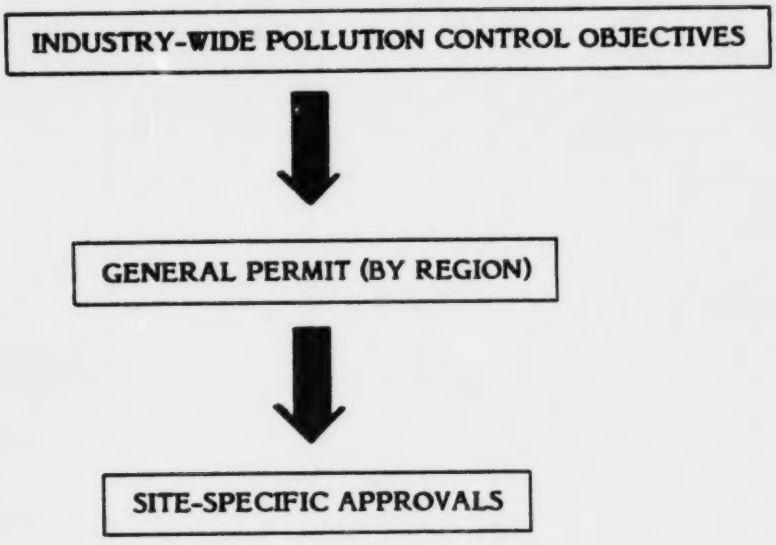
OFFSHORE PRODUCTION WASTE DISCHARGES

REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGES

- REGULATORY APPROACH
- BASIS FOR OBJECTIVES AND PERMIT CONDITIONS
- SUBSTANCES AND WASTES TO BE REGULATED

REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGES

REGULATORY APPROACH



REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGE

POLLUTION CONTROL OBJECTIVES

- Marine environmental quality
- Pollution control technology and practice

- Maximum discharge limits for certain substances and wastes

- Prohibition of highly toxic and persistent substances

REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGES

GENERAL PERMIT

- applies to all operators in a region in compliance with pollution control objectives

SITE-SPECIFIC APPROVALS

- platform-by-platform basis
- approval for waste treatment and disposal system
- acceptance of proposed operational practices

REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGES

BASIS FOR OBJECTIVES AND PERMIT CONDITIONS

- Options
  - base on Best Practical Control Technology
  - base on acceptable level of environmental effect
- Loading rate vs effluent concentration

REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGES

SUBSTANCES AND WASTES TO BE REGULATED

Oil

- TOTAL OIL
  - produced water
  - ballast water
  - storage displacement water
  - oily cuttings
- TOTAL AROMATIC HYDROCARBONS
  - produced water
  - ballast water
  - oily cuttings
- measure total oil by infrared (IR) spectrophotometry
- measure aromatic oil by U.V. fluorescence spectrophotometry
- treatment plant upsets must be considered
- prohibit discharge of oil-base muds

REGULATORY FRAMEWORK FOR OFFSHORE PRODUCTION WASTE DISCHARGES

SUBSTANCES AND WASTES TO BE REGULATED

Persistent and Non-Naturally Occurring Chemicals

- OPTIONS
  - monitoring/reporting of offshore use
  - screening of sources of supply for major substances which are known to be occasional contaminants
  - specification of approved generic drilling fluids
  - chemical identification of compounds used offshore
  - application of a list of approved substances
  - prohibition of use of certain substances offshore

INFORMATION DEFICIENCIES

AND

RESEARCH NEEDS

INFORMATION DEFICIENCIES AND RESEARCH NEEDS

- WASTE CHARACTERISTICS
- TREATMENT AND DISPOSAL TECHNOLOGY
- ENVIRONMENTAL FATE AND EFFECTS

INFORMATION DEFICIENCIES AND RESEARCH NEEDS

WASTE CHARACTERISTICS

- INFORMATION DEFICIENCIES
  - formation water characteristics in Canadian offshore regions
  - characteristics of minor wastes
  - contamination of cuttings by formation oil
- RESEARCH NEEDS
  - formation water
    - evaluation of existing data
    - collection and analysis of samples from Grand Banks, Scotian Shelf, Beaufort Sea fields

INFORMATION DEFICIENCIES AND RESEARCH NEEDS

TREATMENT AND DISPOSAL TECHNOLOGY

- INFORMATION DEFICIENCIES
  - effects of treatment plant upsets on effluent quality
  - effectiveness of treatment systems for removing aromatic hydrocarbons
  - application of existing treatment and disposal technologies to cold temperatures and other conditions in the Canadian offshore
- RESEARCH NEEDS
  - detailed evaluation of the cause, nature, frequency and duration of offshore oily water treatment system upsets
  - evaluation of effectiveness of oily water treatment systems for removing aromatic hydrocarbons
  - applicability, adaptability and cost of oily water treatment and disposal systems and oily cuttings treatment systems to Canadian conditions

INFORMATION DEFICIENCIES AND RESEARCH NEEDS

ENVIRONMENTAL FATE AND EFFECTS

- INFORMATION DEFICIENCIES
  - variability of the physical, chemical and biological components of the North Atlantic
  - biological effects of produced water and oiled cuttings on species indigenous to Canadian East Coast and Arctic Waters
- RESEARCH NEEDS
  - field and model studies on the processes affecting dispersion of wastes
    - sediment transport
    - ice cover
  - review of current North Sea research on long-term accumulation of aromatic hydrocarbons and effects of oil-base mud systems

SESSION 2

TECHNICAL RESULTS

TOPICS FOR SESSION 2

- CHARACTERISTICS OF OFFSHORE PRODUCTION WASTES
- DISCHARGE AND DISPOSAL PRACTICES
- WASTE TREATMENT TECHNOLOGY
- DISCHARGE REGULATIONS
- BIOLOGICAL EFFECTS OF PRODUCTION WASTES
- PREDICTED ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS
- BIOLOGICAL CONCERNS FOR CANADIAN OFFSHORE REGIONS

OFFSHORE OIL AND GAS PRODUCTION WASTES

Major Discharges

- produced water
- drilling fluids and cuttings
- ballast water
- storage displacement water

OFFSHORE OIL AND GAS PRODUCTION WASTES

Minor Discharges

- Produced Sand
- Deck Drainage
- Well Completion and Workover Fluids
- Miscellaneous Well Fluids (cement, BOP fluid)
- Sanitary and Domestic Wastes
- Gas and Oil Processing Wastes
- Miscellaneous Discharges
  - slop oil
  - cooling water
  - desalination brine
  - fire control system test water

CHARACTERISTICS OF OFFSHORE PRODUCTION WASTES

- Produced Water
- Water-base Drilling Muds and Cuttings
- Oil-base Drilling Muds and Cuttings
- Ballast and Storage Displacement Water
- Minor Wastes

PRODUCED WATER

COMPOSITION

- dissolved salts
- dissolved and colloidal hydrocarbons
- trace metals
- chemical additives
- suspended solids

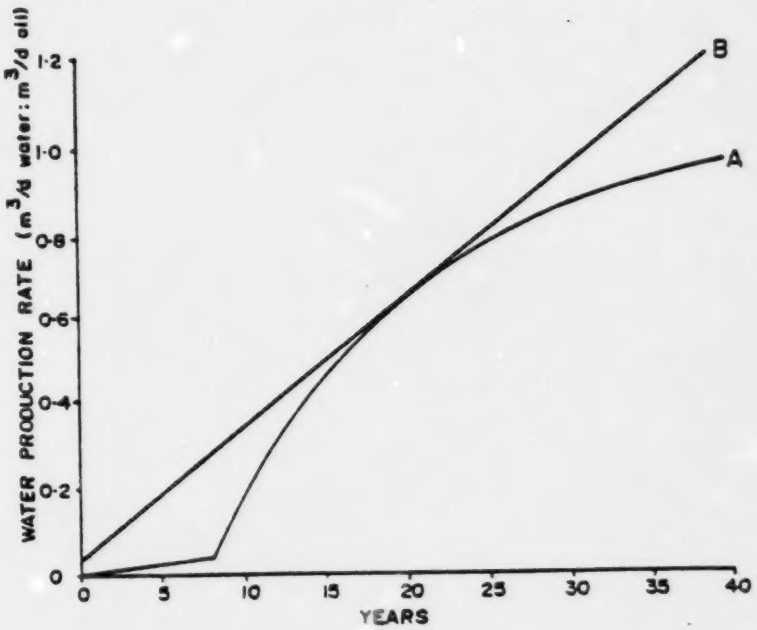
PRODUCED WATER DISCHARGE RATES

m^3/d

	TYPICAL VALUE	RANGE
Gulf of Mexico	1 000	16 - 40 000
Coastal California	1 200	40 - 4 000
Cook Inlet	10 000	200 - 17 000
North Sea	2 000	400 - 10 000

PRODUCED WATER DISCHARGE RATES

	RANGE (m^3/d)	WATER : HYDROCARBON
Gas Production	50 - 300	6 m^3 water/10^6 m^3 gas
Oil Production	20 - 40 000	0.3 - 5 m^3 water/m^3 oil



TYPICAL CHANGE IN PRODUCED WATER DISCHARGE OVER OIL FIELD LIFE

MAJOR CONSTITUENTS IN PRODUCED WATER

	TYPICAL VALUE	RANGE
pH	6.5	6 - 9
TDS (mg/L)	100 000	6 000 - 300 000
Oil (GR) (mg/L)	10 - 40	-
Oil (IR) (mg/L)	15 - 55	-
Upset Conditions Oil (mg/L)	-	50 - 400 (GR) 75 - 450 (IR)

GR = Gravimetric
IR = Infra-red
TDS = Total Dissolved Solids

AROMATIC HYDROCARBONS IN PRODUCED WATER

(mg/L)

	TYPICAL VALUE	RANGE
Total Aromatic	5 - 10	-
Benzene	3.5	0.2 - 14
Toluene	2.5	0.2 - 8
Phenol	1.0	0.2 - 3.4
Ethylbenzene	0.2	0.03 - 0.55
Naphthalene	0.1	0.02 - 0.3

DISSOLVED METALS IN PRODUCED WATER

(mg/L)

	TYPICAL VALUE	RANGE
Iron	-	1 - 100
Zinc	0.2	0.03 - 0.6
Chromium	0.1	0.02 - 0.4
Cadmium	0.03	0.02 - 0.2

DRILLING FLUIDS AND CUTTINGS

- water-base mud systems
- oil-base mud systems

WATER-BASE DRILLING MUDS

MAJOR CONSTITUENTS

- barite
- bentonite
- lignosulphonates (chrome and ferrochrome)
- lignite
- caustic soda
- sodium carbonate/bicarbonate

WATER-BASE DRILLING MUDS

MINOR CONSTITUENTS

- potassium chloride
- surfactants and detergents
- corrosion inhibitors
- lubricants
- biocides
- others

DRILLING FLUID AND CUTTINGS DISCHARGE

	FLUID	CUTTINGS
Continuous (m^3/d)	90 - 8	40 - 6
Bulk (m^3)	8 x 100 m^3	-
Total/well (m^3)	2 000 - 3 000	800 - 1 500
Total/platform (m^3) (40 wells)	90 000 - 125 000	30 000 - 60 000

WATER-BASE DRILLING MUDS
TYPICAL TRACE METAL CONCENTRATIONS

	FLUID (mg/L)	CUTTINGS (mg/kg)
Cadmium	1 - 8	1.5
Chromium	80 - 190	30
Mercury	0.03	0.05

OIL-BASE DRILLING MUD SYSTEMS

- Oil is the carrier for all other additives
- Brine is emulsified in the oil
- Drilling fluids not discharged to sea
- Cuttings discharged to sea with or without cleaning
- Use
  - deviated development wells
  - sensitive formations
  - increase lubrication

OIL CONTENT OF OIL-BASE DRILLING MUDS

MUD SYSTEM	TOTAL OIL (Vol. % of mud)	AROMATICS (Vol. % of oil)
Diesel Oil	60	25 - 30
Paraffin Oil	30 - 60*	5 - 20
Specialty Paraffin Oil	60*	0.3 - 1

* assumed

RESIDUAL OIL ON CUTTINGS DISCHARGES

MUD SYSTEM	CUTTINGS CLEANER	CUTTINGS OIL CONTENT (wt. %)
Diesel Oil	yes	10 - 20
Paraffin Oil	no	5 - 20
Specialty Oil	no	10

DISCHARGE RATES FOR TANKER BALLAST WATER

	TYPICAL VALUE	RANGE
Storage Capacity (m^3)	150 000	30 000 - 225 000
Discharge Rate (m^3/d)	50 000	10 000 - 200 000

CHARACTERISTICS OF TANKER BALLAST WATER AND STORAGE DISPLACEMENT WATER

	BALLAST WATER	STORAGE DISPLACEMENT WATER
TDS	same as source sea water	same as surrounding sea water
Total Oil (mg/L)	2 - 15	10 mg/L
Aromatics (mg/L)	5 - 10	-
Metals	reflects water sources	reflects water sources

CHARACTERISTICS OF MINOR WASTE DISCHARGES

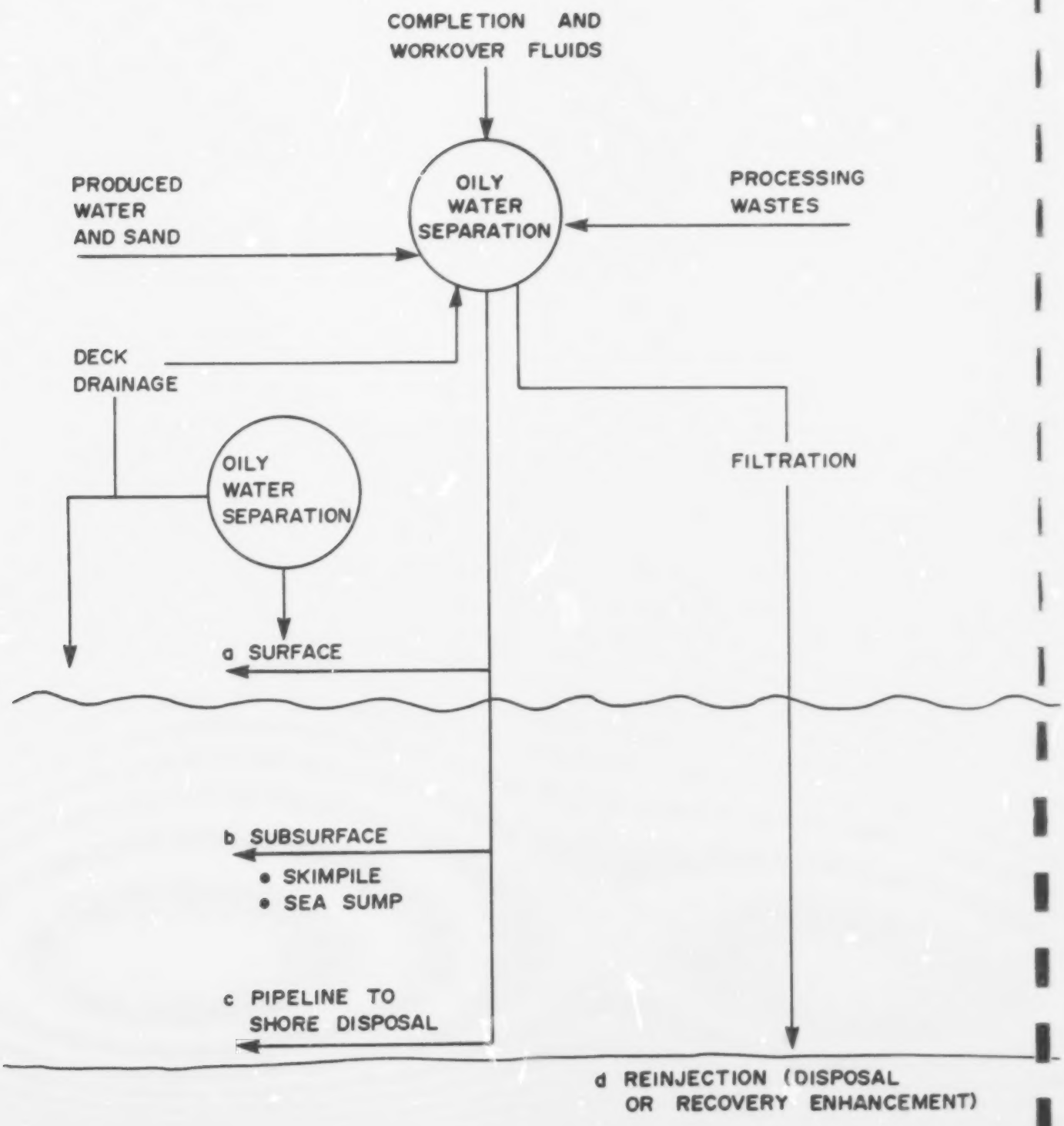
	COMPOSITION	VOLUME/DISCHARGE
Produced Sand	• formation solids 1 + mg/L oil	1 - 50 m^3/d
Deck Drainage	• 25–100 mg/L lubricating oil detergents	1 - 1 500 m^3/d
Completion/Workover Fluids	• acids chlorides and bromides	5 - 150 m^3/well
BOP Fluid	• vegetable oil ethylene glycol	140 m^3/well
Excess Cement	• calcium oxide/ silicate	6 - 100 m^3/well
Sanitary Waste	• 30 mg/L BOD 40 mg/L SS	10 - 15 m^3/d combined
Domestic Waste	• 195 mg/L BOD 140 mg/L SS	

CHARACTERISTICS OF MINOR WASTE DISCHARGES

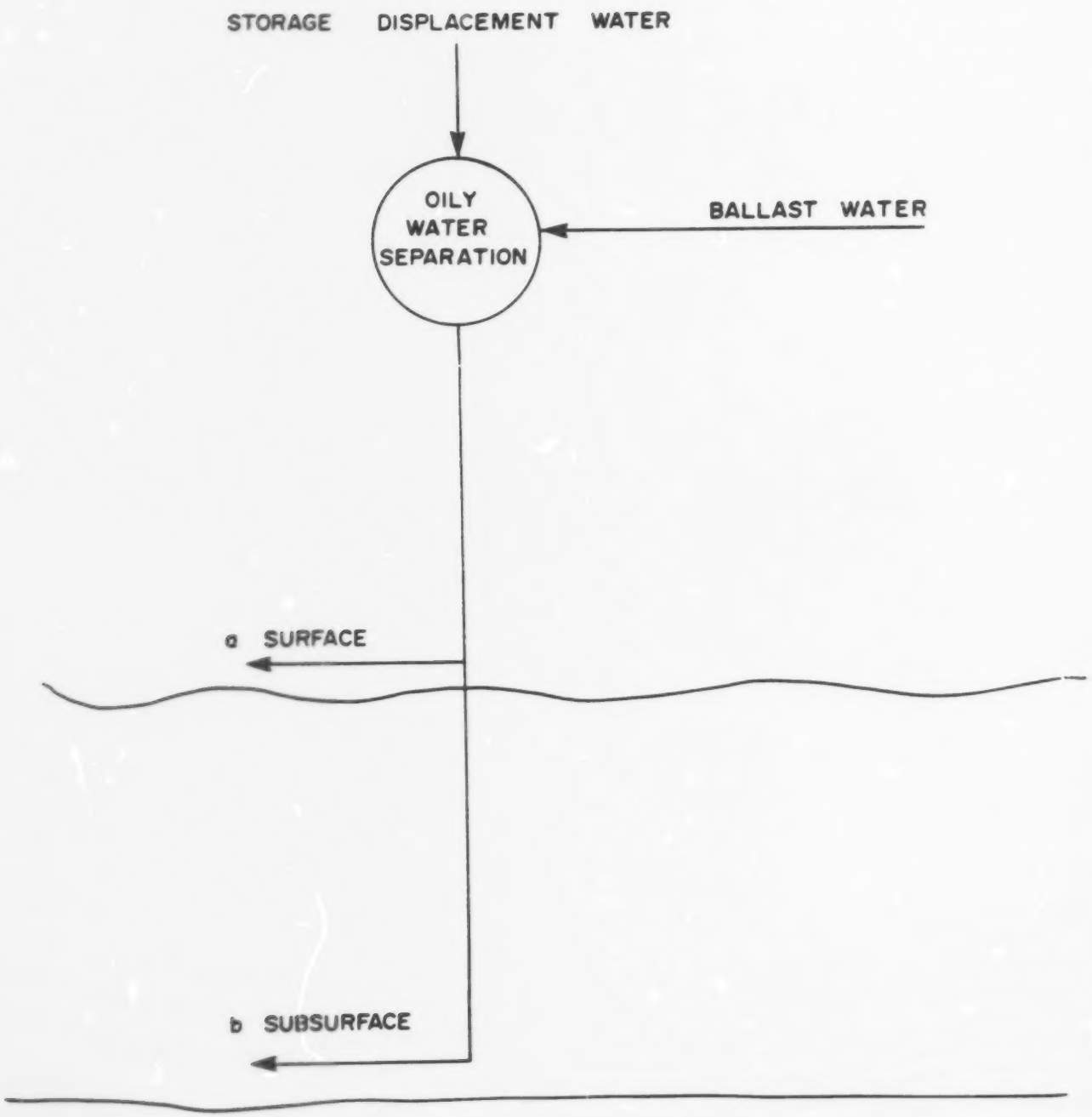
	COMPOSITION	VOLUME DISCHARGE
Gas and Oil Processing Wastes	• glycols lubricating oils	10 - 100 m^3/d
Slop Oil/Sludges	-	hauled to shore
Cooling Water	• Δ + 10 - 30°C • 0.5 mg/L chlorine	500 - 70 000 m^3/d
Desalination Brine	• concentrated sea salts	20 - 30 m^3/d
Fire Control Test Water	• chlorine in sea water	10 - 65 000 m^3/d

DISCHARGE AND DISPOSAL PRACTICES

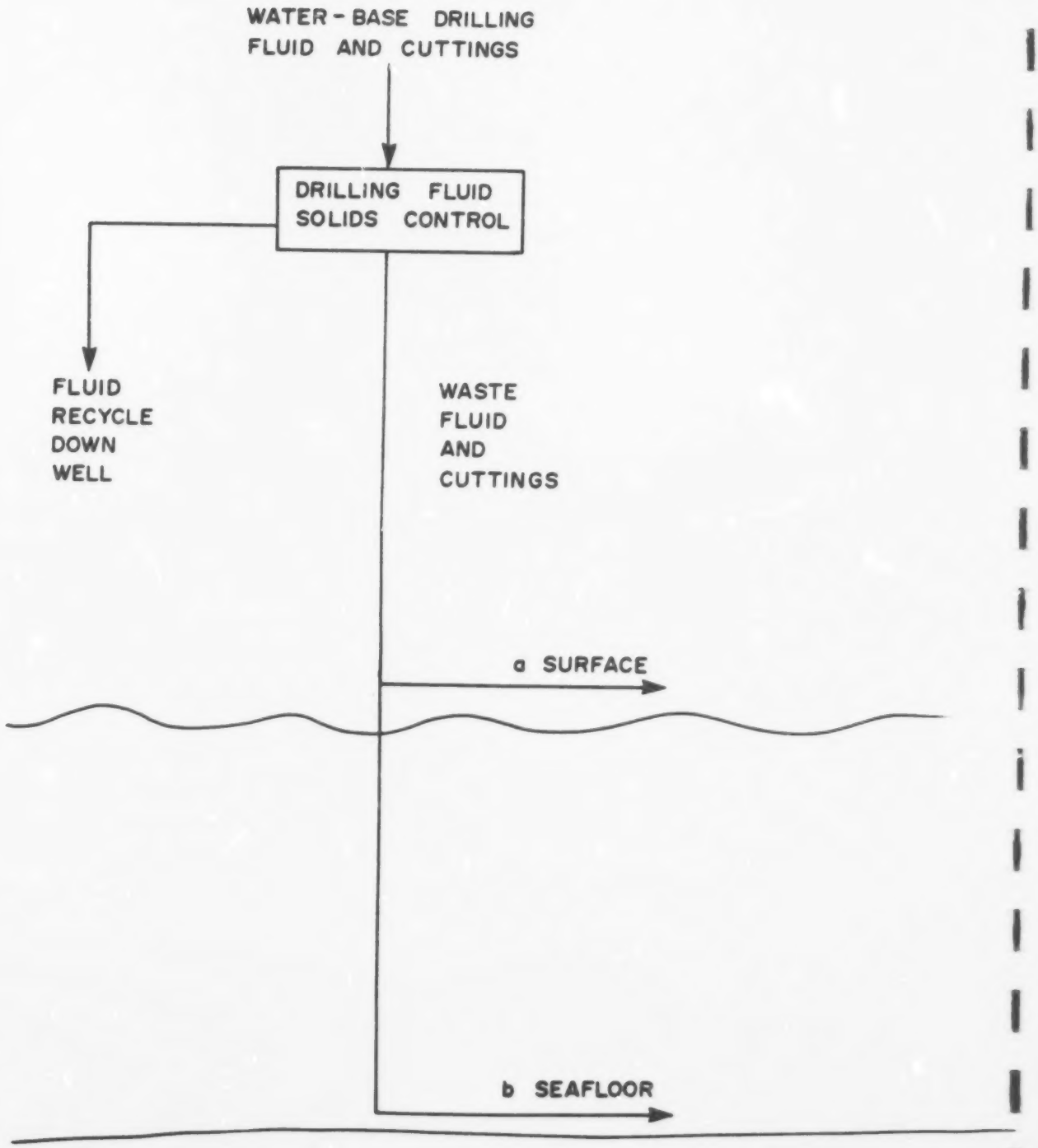
METHODS FOR DISCHARGE OF OFFSHORE PRODUCTION WASTES



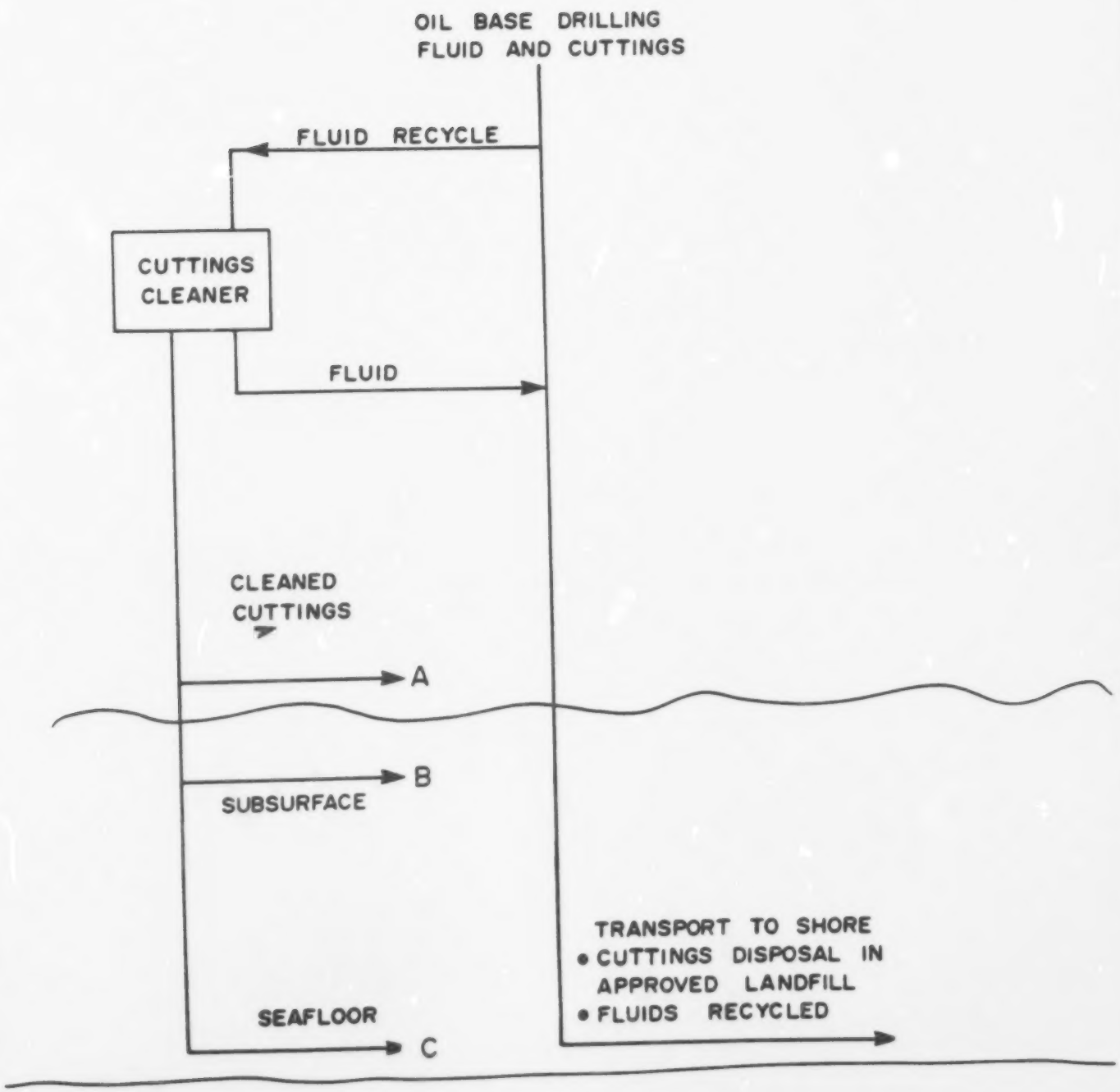
METHODS FOR DISCHARGE OF OFFSHORE PRODUCTION WASTES



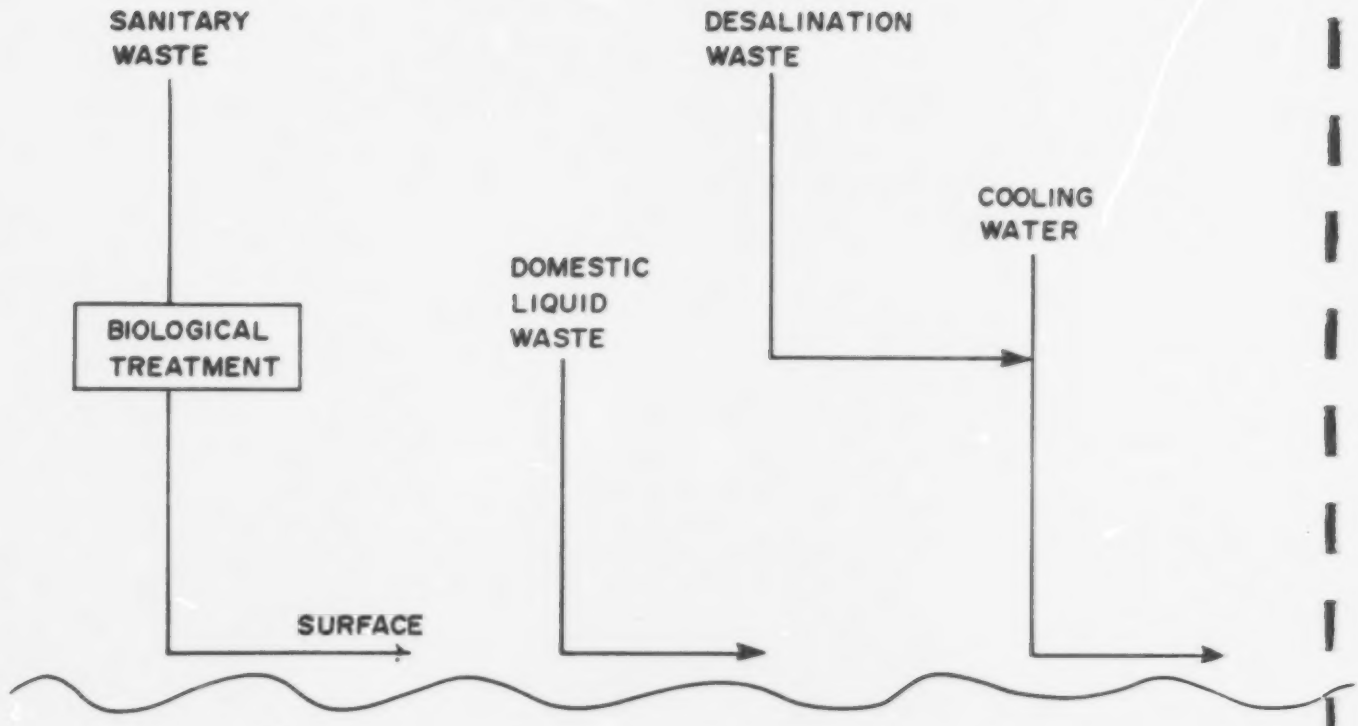
METHODS FOR DISCHARGE OF OFFSHORE PRODUCTION WASTES



METHODS FOR DISCHARGE OF OFFSHORE PRODUCTION WASTES



METHODS FOR DISCHARGE OF OFFSHORE PRODUCTIONS WASTES



METHODS FOR DISPOSAL OF PRODUCED WATER

METHOD	ADVANTAGES	DISADVANTAGES
1. surface ocean disposal	• low cost • simple	• no backup for treatment upset
2. subsea through sea sump	• simple • disperses oil deep for treatment upset	• increased capital cost
3. subsea through skim pile	• simple • backup oil skimming	• increased capital and operating cost
4. pipeline to shore/ coastal outfall	• feasible for nearshore platforms in shallow water • reduced space and equipment requirement on platform	• coastal discharge may require higher level oil removal
5. injection into formation	• no ocean discharge of oil • for sensitive marine environment	• high capital and operating cost • depends on suitable formation • increased treatment required

METHODS FOR DISPOSAL OF DRILLING FLUIDS AND CUTTINGS

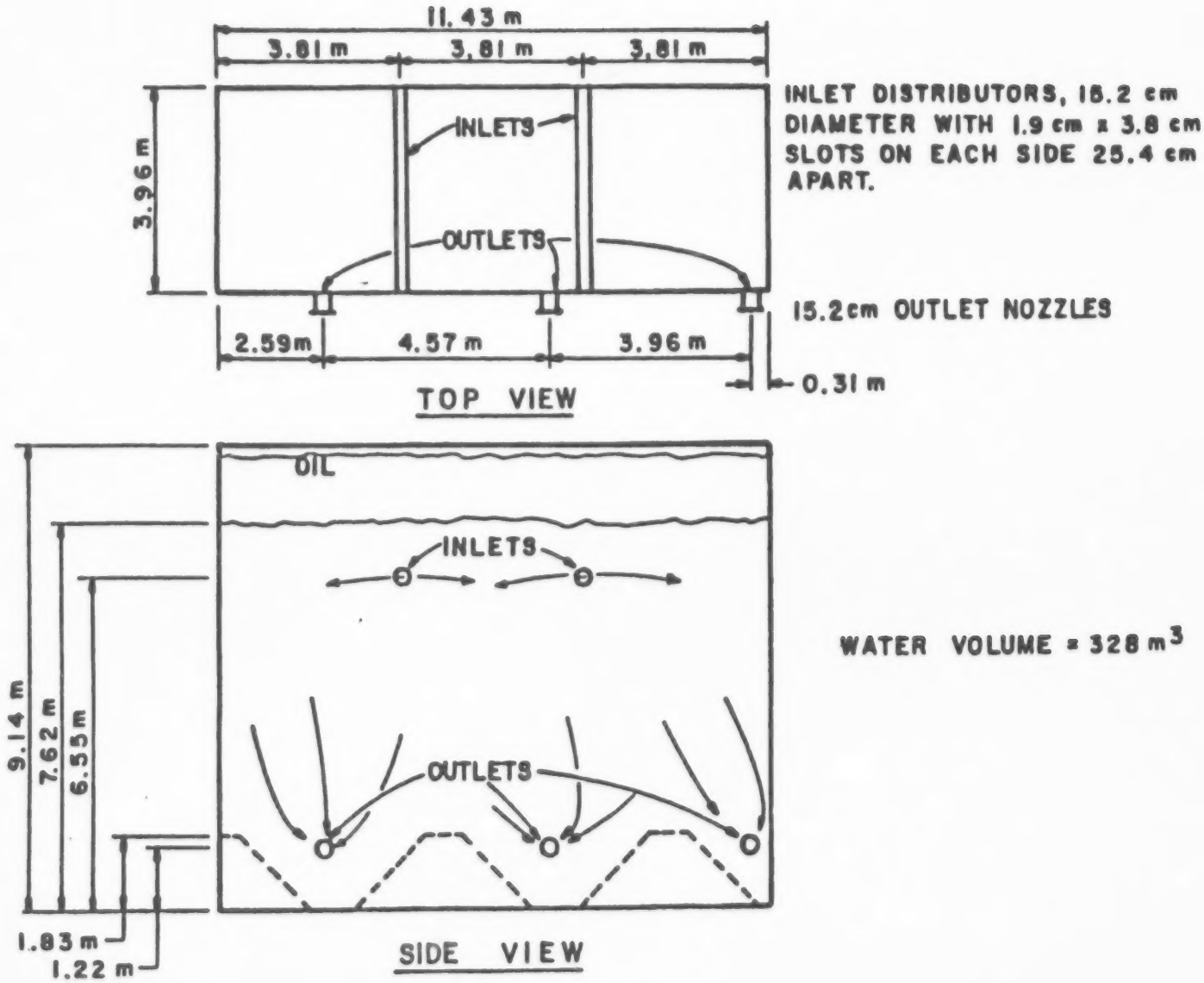
METHOD	ADVANTAGES	DISADVANTAGES
1. surface discharge	• low cost • adequate with rapid dispersion/dilution upon discharge	• locally high suspended solids
2. surface discharge with dilution/ neutralization	• dilution of toxic substances • low cost	• need is disputed
3. shunting to sea floor	• useful for discharge adjacent to sensitive environments • deposition of material to small area	• additional cost/not required for non-sensitive environment
4. transportation to remote ocean site	• eliminates discharge to sensitive environments	• high cost of transportation • requires offshore storage on platform or barge
5. transportation to land disposal site	• eliminates discharge to sensitive marine environments	• high cost of transportation • additional offshore storage • logistics/downtime • problems with land disposal

WASTE TREATMENT TECHNOLOGY

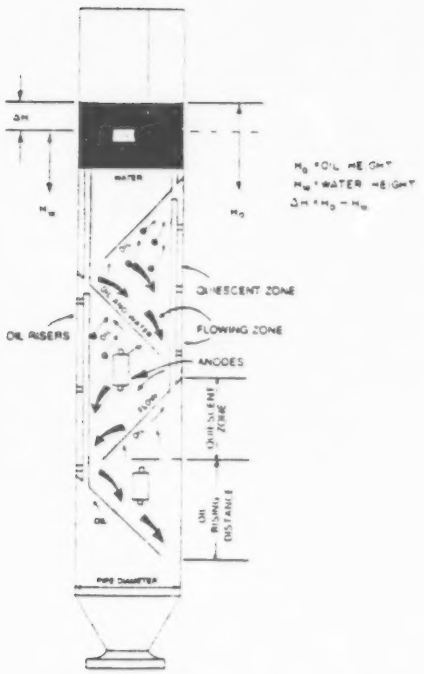
- OILY WATER TREATMENT
- OILY CUTTINGS CLEANING
- TREATMENT AND HANDLING OF MINOR WASTES

METHODS FOR OILY WATER TREATMENT

- skim tank
- skim pile
- plate coalescers
- flotation units
- fibrous and granular media coalescers



SKIM TANK FOR PRIMARY OIL REMOVAL



SKIM PILE FOR OIL REMOVAL AND DISPOSAL

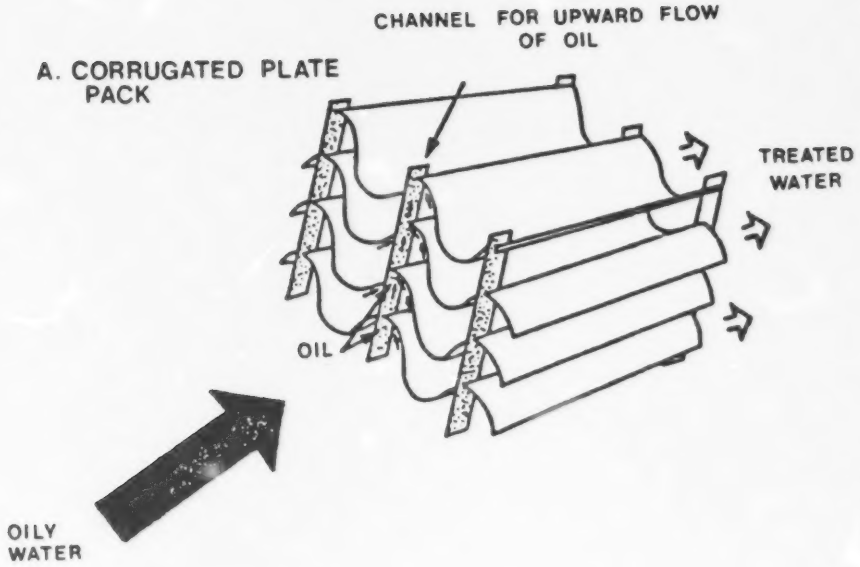
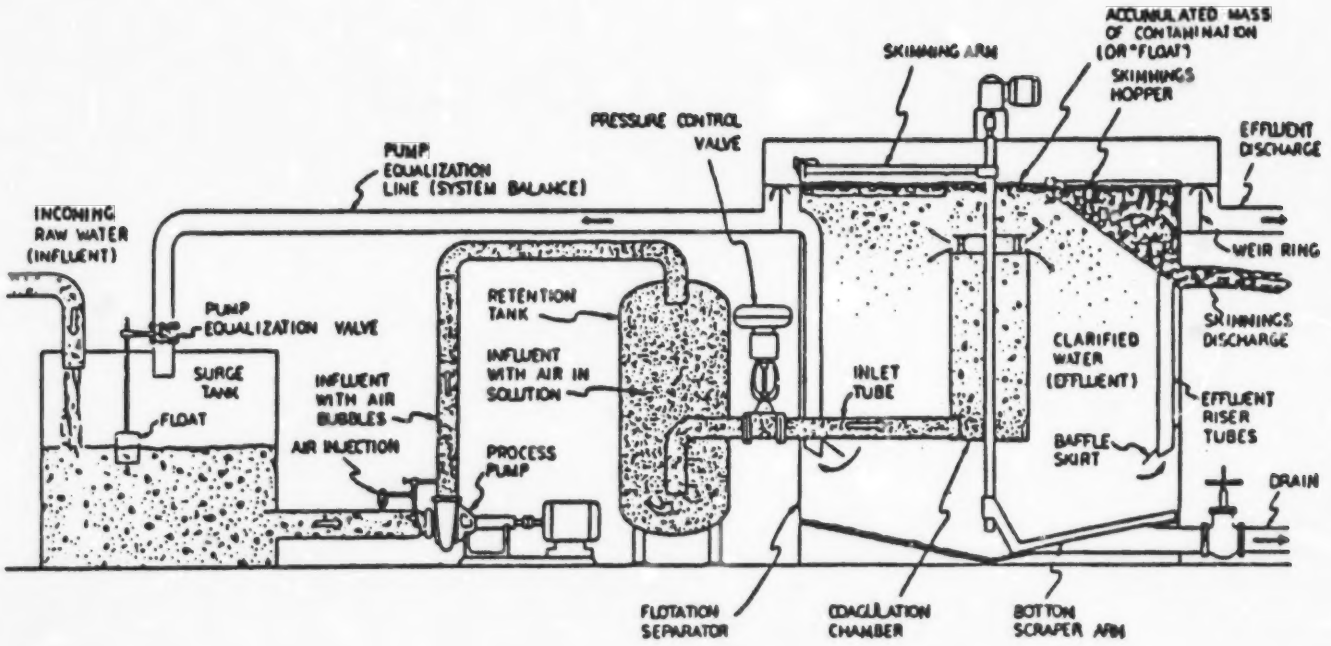
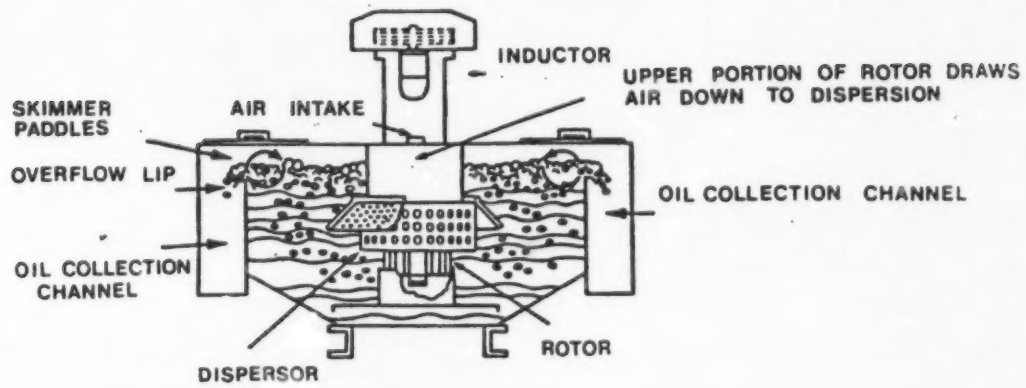


PLATE COALESCER

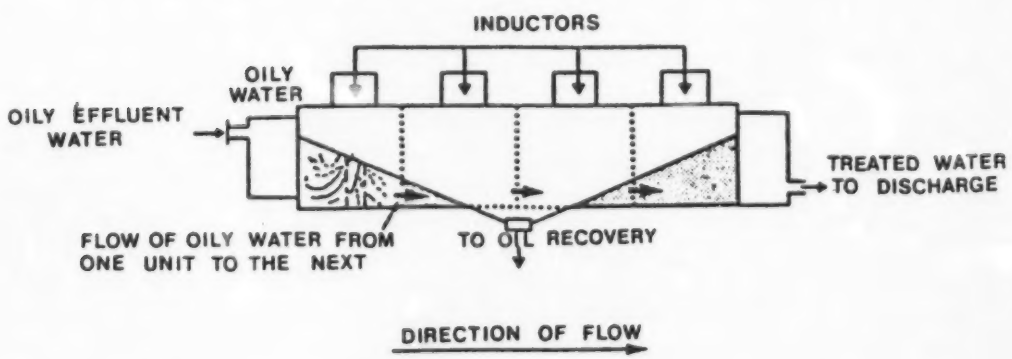


DISSOLVED AIR FLOTATION UNIT

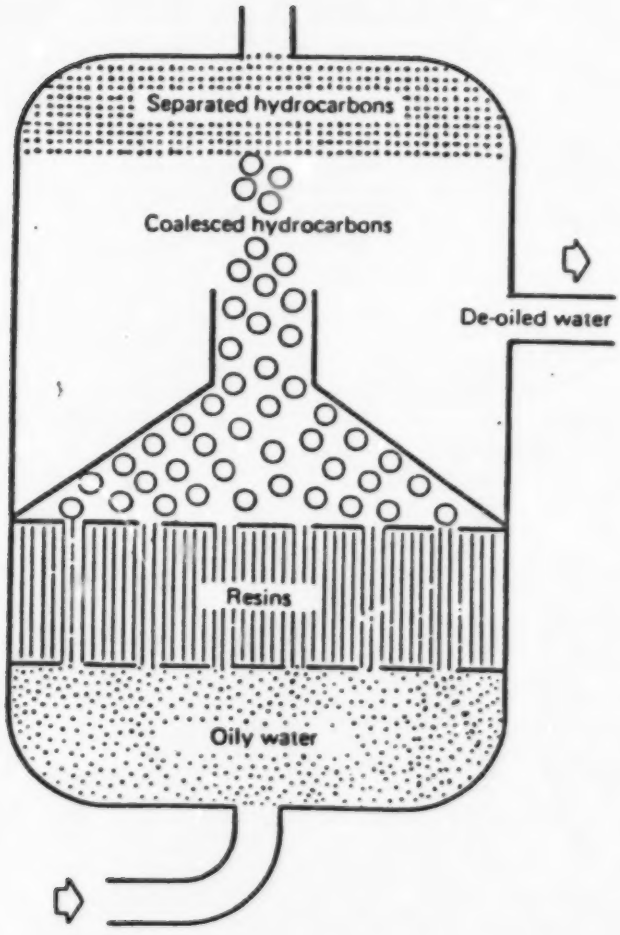
A. Transverse section of a gas flotation unit



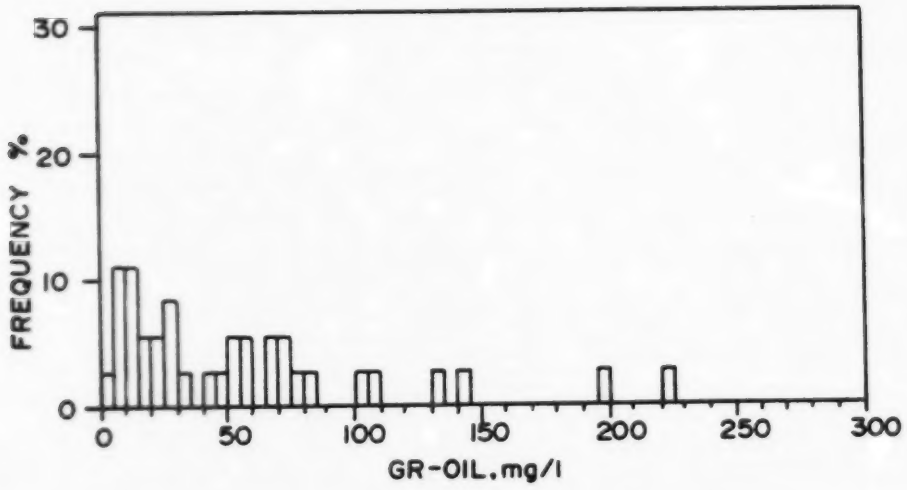
B. Longitudinal section of a four-unit system



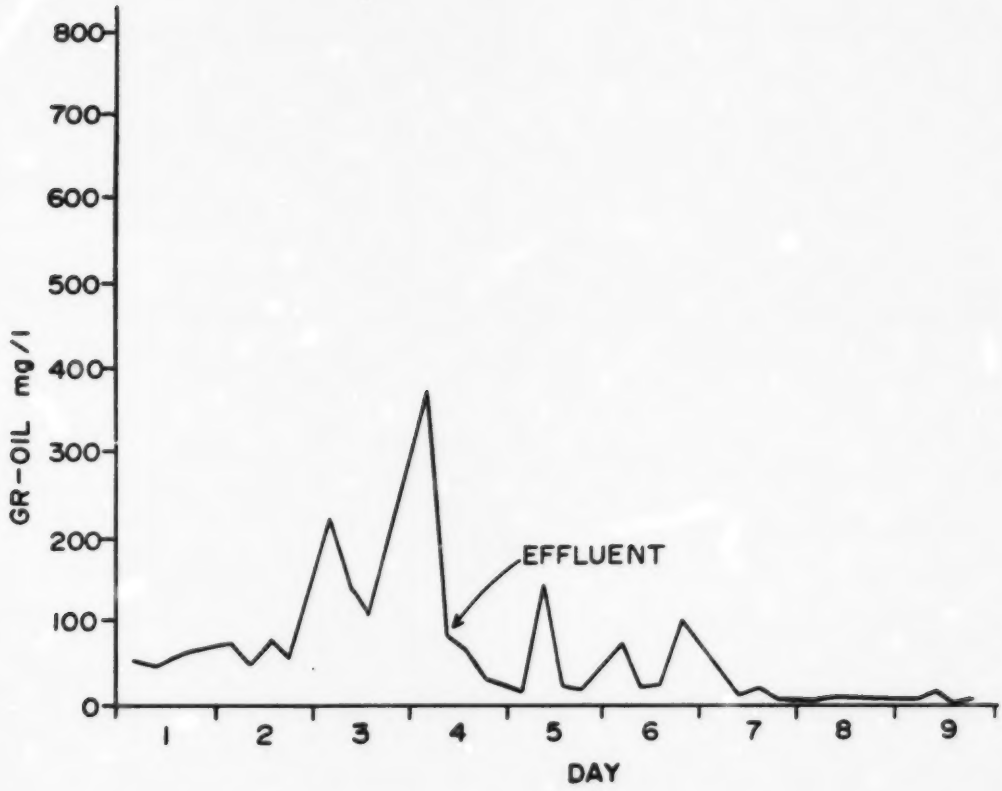
DISPERSED AIR FLOTATION



GRANULAR MEDIA COALESCER



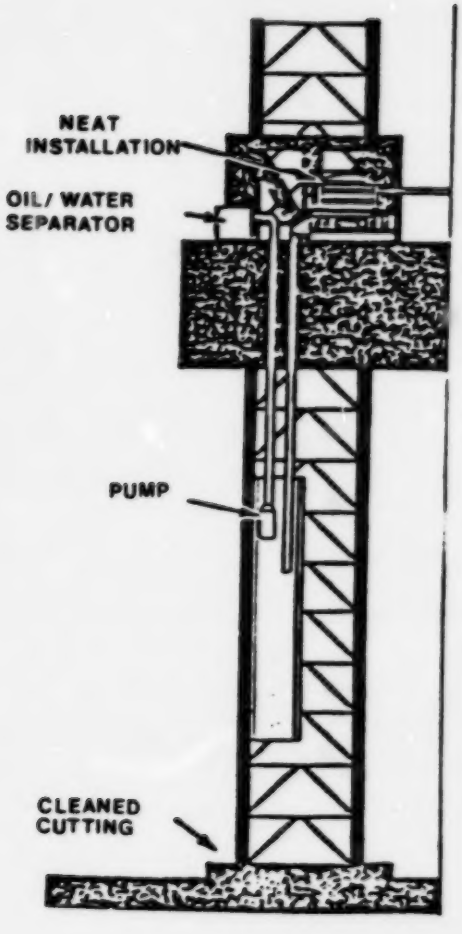
PRODUCED WATER TREATMENT FLOTATION UNIT VARIABILITY/UPSET CONDITIONS



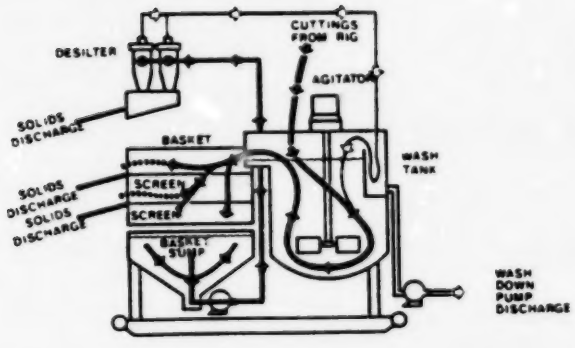
PRODUCED WATER TREATMENT FLOATATION UNIT
VARIABILITY / UPSET CONDITIONS

METHODS FOR CLEANING OILY DRILL CUTTINGS

	OIL REMAINING ON CUTTINGS (wt. %)
CURRENT	
• water or diesel spray wash	20 - 30
• water and detergent immersion wash	10 - 20
STATE-OF-THE-ART	
• vacuum distillation (Crew)	< 1
• hot air evaporation (Swaco)	< 1
• solvent extraction with CO_2 or freon (Critical Systems)	< 1
• fluidized bed incineration	-
• decant centrifugation	5



NORTH SEA OIL-BASE
CUTTINGS DISPOSAL



BRANDT OILY CUTTINGS WASHER

TREATMENT/HANDLING OF NON-OILY MINOR WASTES

WASTE	HANDLING
• produced sand	• water or detergent wash
• sanitary waste	• extended aeration and chlorination/ surface discharge
• domestic waste	• masceration/surface discharge
• gas/oil processing wastes	• gravity separation and discharge through sea sump
• slop oil/sludges	• shore disposal
• completion/workover fluids	• treated with produced water
• BOP fluid	• discharge to sea floor
• excess cement	• discharge to sea floor

DISCHARGE REGULATIONS

NATIONAL APPROACHES TO REGULATION OF OFFSHORE PRODUCTION WASTES

CANADA

- standard for oil in produced water
- approval of each platform design
- acceptance of performance by COGLA
- basis for standards not stated

U.S.

- industry-wide oily waste discharge standards based on Best Practical Technology (BPT)
- General Permits issued on regional basis
- general requirement for "no surface sheen"

U.K.

- maximum standard for oil discharge based on equipment performance (BPT)
- permits issued for each platform with specific limit
- notification scheme for selection of chemicals for offshore use

NORWAY

- oily waste discharge limits set by permit for each platform
- based on Best Practical Technology (BPT)
- general restrictions on discharge of poisonous chemicals

DISCHARGE REGULATIONS OR PERMIT CONDITIONS FOR PRODUCED WATER

	OIL (MONTHLY AVG.) (mg/L)	OIL (DAILY AVG.) (mg/L)	TRACE METALS (mg/L)
Canada	-	35	-
Gulf of Mexico	-	72 (GR)	-
Coastal California	-	72 (GR)	As 0.032 Cd 0.012 Hg 0.00056 several others
Cook Inlet	48 (GR)	72 (GR)	-
U.K.	40 (IR) - large 50 (IR) - small	- -	Hg, Cd prohibited
Norway	25 (IR) - large 30 (IR) - small	- -	- -

GR = gravimetric analysis
IR = infrared analysis

DISCHARGE REGULATIONS FOR OTHER OILY WASTES

	BALLAST WATER	DECK DRAINAGE
Canada	-	-
Gulf of Mexico	-	no free oil/surface sheen
Coastal California	-	no free oil/surface sheen
Cook Inlet	oil: 8 mg/L (mean) aromatics: 6 mg/L (mean)	oil - 90 mg/L (max.)
U.K.	offshore: 40 mg/L oil (IR) onshore: 5-25 mg/L oil (IR)	-
Norway	best practical treatment	permit required

IR = Infrared Analysis

DISCHARGE REGULATIONS FOR DRILLING FLUIDS AND CUTTINGS

	OIL-BASE MUD	OIL-BASE CUTTINGS
Canada	Draft:* • no diesel • aromatic less than 5% • no mud discharge	Draft: • less than 15% oil on cuttings • no discharge in less than 20 m water
Gulf of Mexico	offshore discharge prohibited	• no free oil on surface
Coastal California	offshore discharge prohibited	• state prohibits discharge
U.K.	offshore discharge prohibited	• diesel: - 5% cuttings wt. (draft) paraffin: - 15% (draft)
Norway	approval of treatment and holding facility	• diesel: 50-150 L/m^3 oil on cuttings paraffin: by permit

* February 1984

DISCHARGE REGULATIONS FOR CHEMICAL ADDITIVES AND TRACE METALS IN PRODUCTION WASTES

	CHEMICAL ADDITIVES	TRACE METALS
Canada	• drilling chemicals screened	• drilling chemicals screened
Gulf of Mexico	• halogenated phenols prohibited • surfactants/dispersants to be minimized	-
Coastal California	• certain toxic materials prohibited 0.12 mg/L phenol in produced water 0.02 mg/L cyanide in produced water • halogenated phenols prohibited	• limits for As, Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn in produced water
U.K.	• organohalogens prohibited	• mercury, cadmium prohibited

BIOLOGICAL EFFECTS OF PRODUCTION WASTE

- Produced Water and Deck Drainage
- Drilling Wastes
- Ballast and Storage Displacement Water
- Produced Sand
- Sanitary and Domestic Wastes
- Oil and Gas Processing Wastes

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

PRODUCED WATER

- only slightly toxic (LC50: 0.1 - 1%) to practically non-toxic (LC50: > 1%)
- limited bioaccumulation
- significant effects on abundance and community structure remote
- effects of temperature, salinity, dissolved oxygen and organic content of produced waters generally a non-issue
- field studies report several positive correlations between offshore oil facilities and biological effects
    - increased histopathological conditions
    - abnormal enzyme activity in fish
    - bioaccumulation of petroleum hydrocarbons in fish and invertebrate tissues

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DECK DRAINAGE

- Effects on marine organisms low
  - limited discharge
  - rapid dilution
  - short exposure of organisms
- Contain toxic chemicals
  - detergents
  - dispersants
  - lubricating oils

DECK DRAINAGE CONSTITUENTS

96h-LC50

CONSTITUENT	TEST ORGANISMS	96h-LC50 (ppm)
Detergents	Fish	1 - 60
Dispersant (Corexit 9527)	Invertebrates	175 - 1000
Lubricating Oil	Invertebrates/Fish Larvae	25000 - 10^5

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

Water-Base Drilling Muds and Cuttings

- SEA WATER COLUMN
  - short-term
  - short-range
- SEDIMENT
  - community
  - toxicity
  - bioaccumulation

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

Water-Base Drilling Muds and Cuttings

COMMUNITY EFFECTS

- benthic infauna affected most
  - smothering
  - reduced abundance/changes in species composition
  - usually no observable effects beyond 500 metres of discharge
- attraction of epifauna and fish to cuttings piles

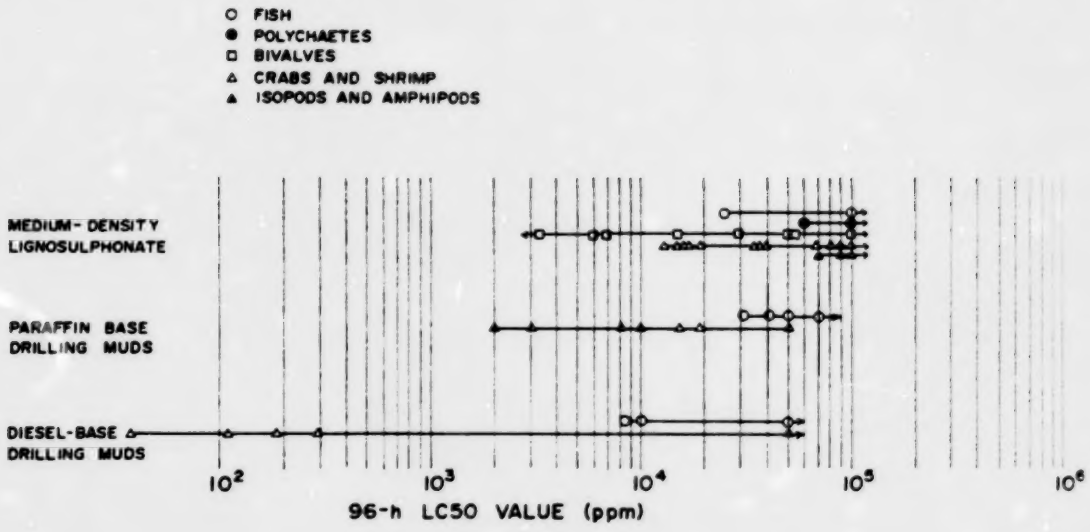
BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

Water-Base Drilling Muds and Cuttings

TOXICITY

- major components practically non-toxic
- whole mud less toxic than individual components
- toxicity is species/individual specific
    - 96h LC50 approx. 1-10 percent
    - variability of LC50 usually < 100 fold for given mud system
- toxicity of clay-chrome lignosulphonate muds only slightly (LC50 : 0.1 to 1%) to practically non-toxic (LC50 : > 1%) for most organisms
- appears to arise from volatile organic components
- biocides
    - highly toxic
    - only limited quantities used


○ FISH
● POLYCHAETES
□ BIVALVES
△ CRABS AND SHRIMP
▲ ISOPODS AND AMPHIPODS
MEDIUM-DENSITY LIGNOSULPHONATE
PARAFFIN BASE DRILLING MUDS
DIESEL-BASE DRILLING MUDS
10²
10³
10⁴
10⁵
10⁶
96-h LC50 VALUE (ppm)

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

Water-Base Drilling Muds and Cuttings

BIOACCUMULATION

- Ba, Cr, Cd, Zn, Pb may accumulate but usually rapid depuration occurs following exposure
- high variability among organisms
- tissue levels do not correlate well with sediment levels
- biological effect difficult to prove

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

Oil-Base Drilling Muds and Cuttings

- SEA SURFACE
  - usually limited to sheen
- WATER COLUMN
  - limited to near-field
- SEDIMENT
  - substrate modification
    - particle size
    - anoxia (organic loading)

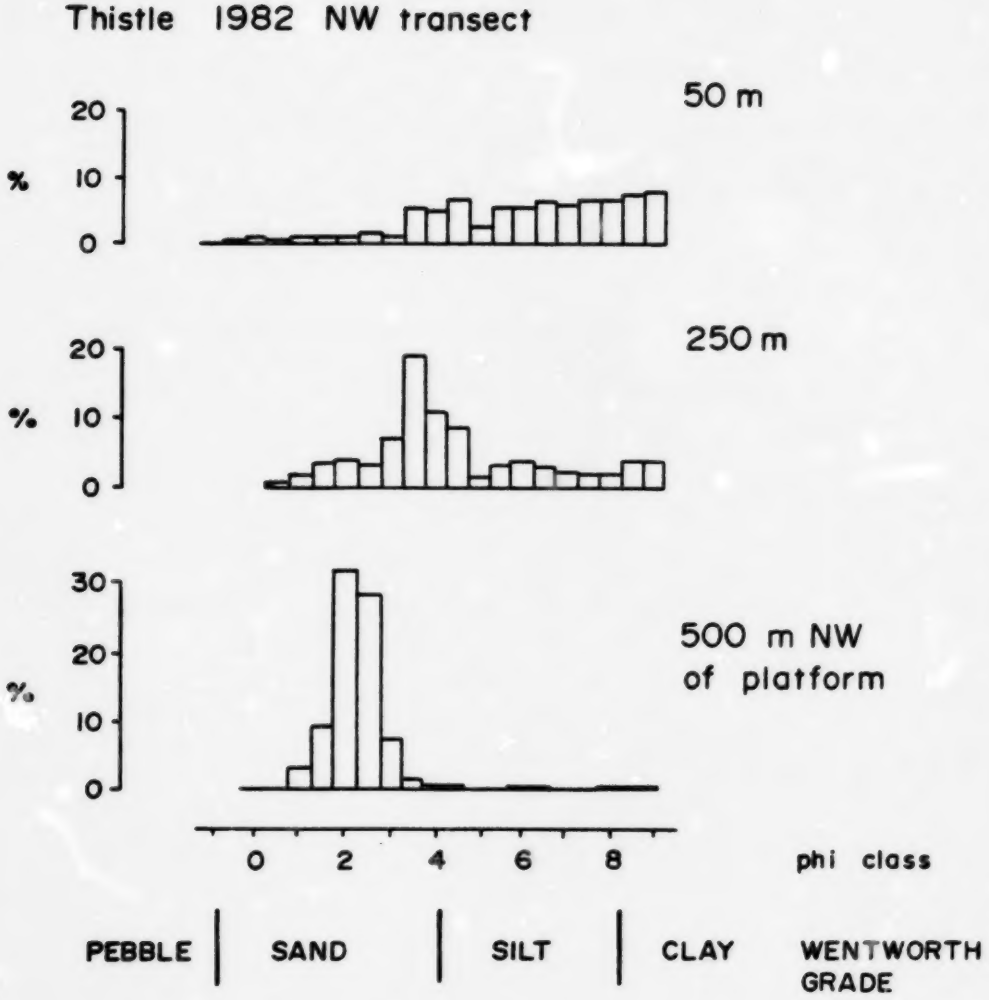
BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

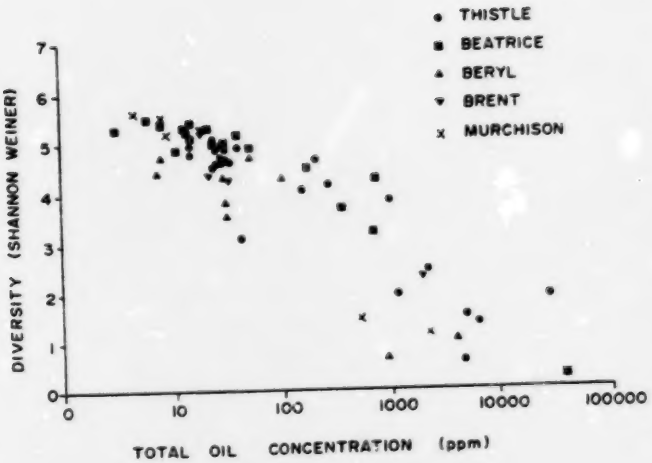
Oil-Base Drilling Muds and Cuttings

Benthic infauna affected most

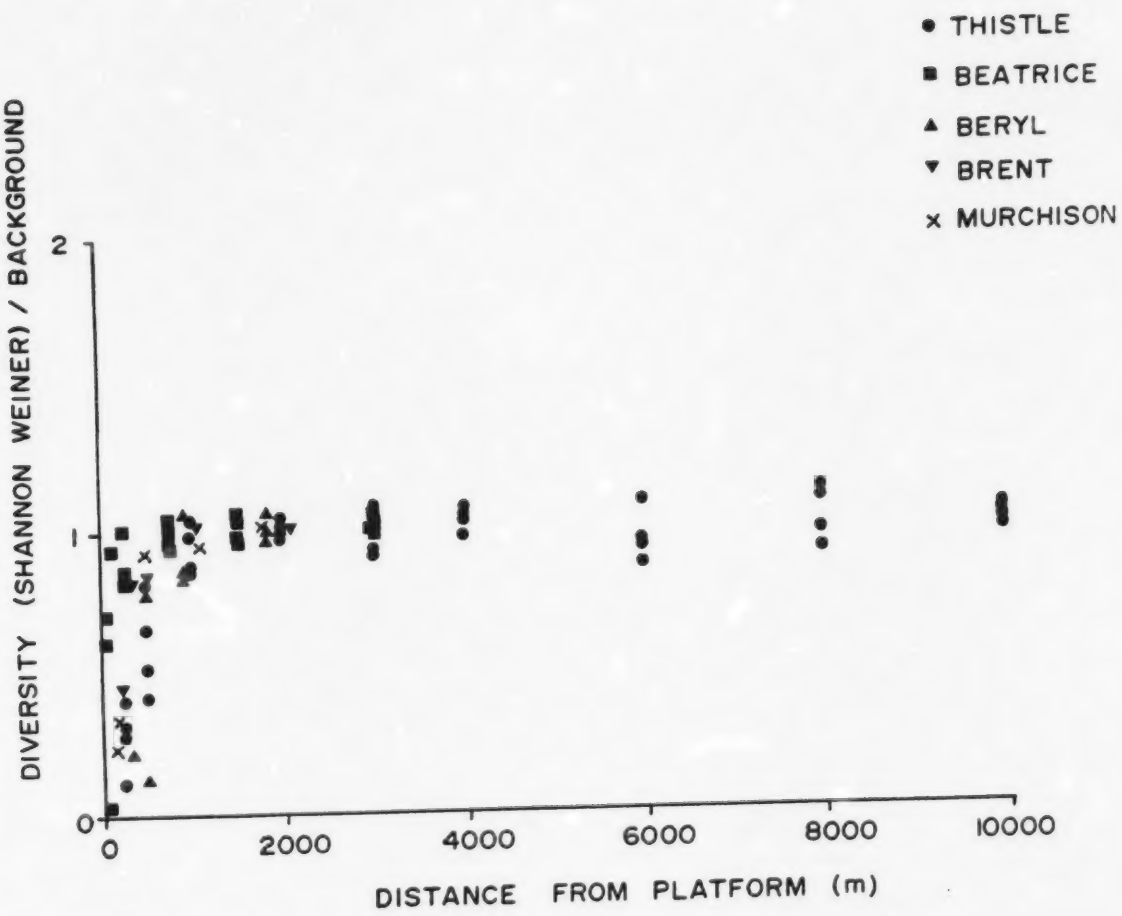
- smothering
- changes in community structure
- toxicity of hydrocarbons
    - diesel oil-base muds 3 to 260 time more toxic than mineral oil-base muds
    - highly dependent on species/life history stage
- bioaccumulation of hydrocarbons



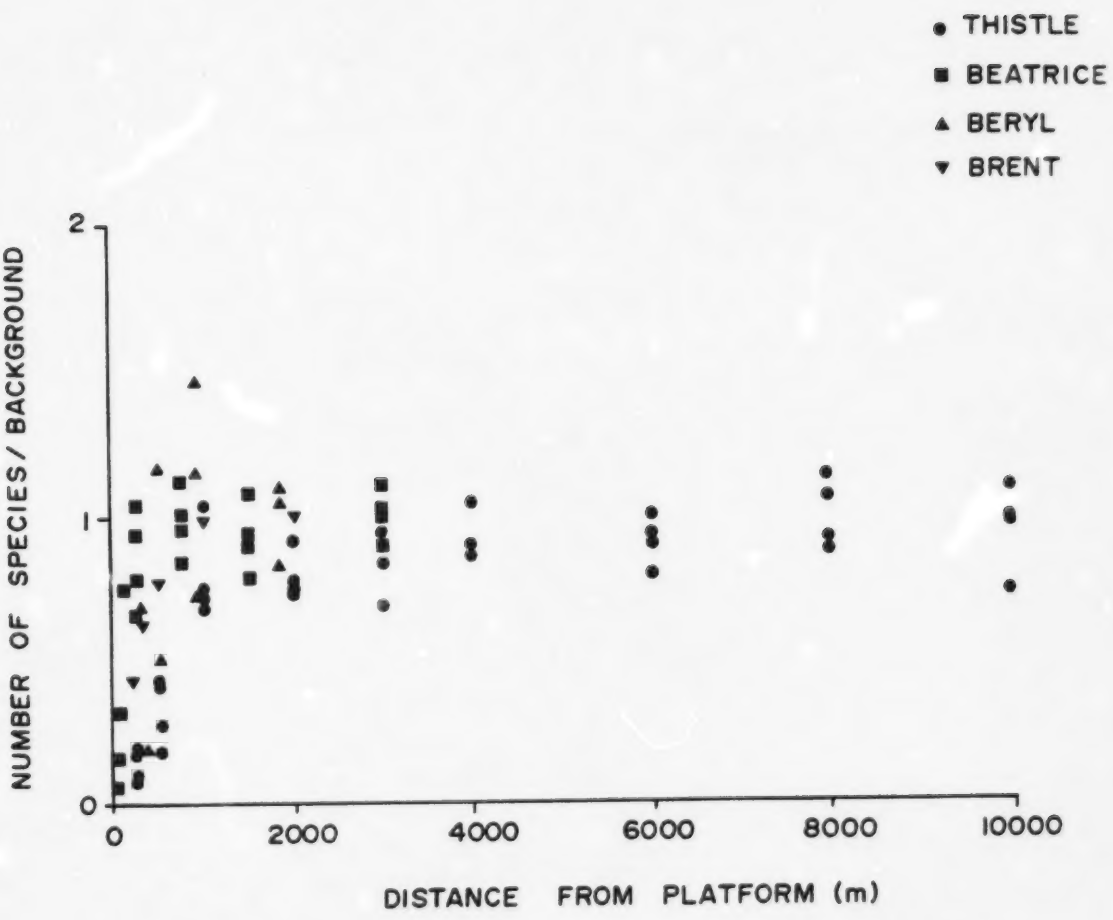
SUBSTRATE ALTERATION AROUND THISTLE



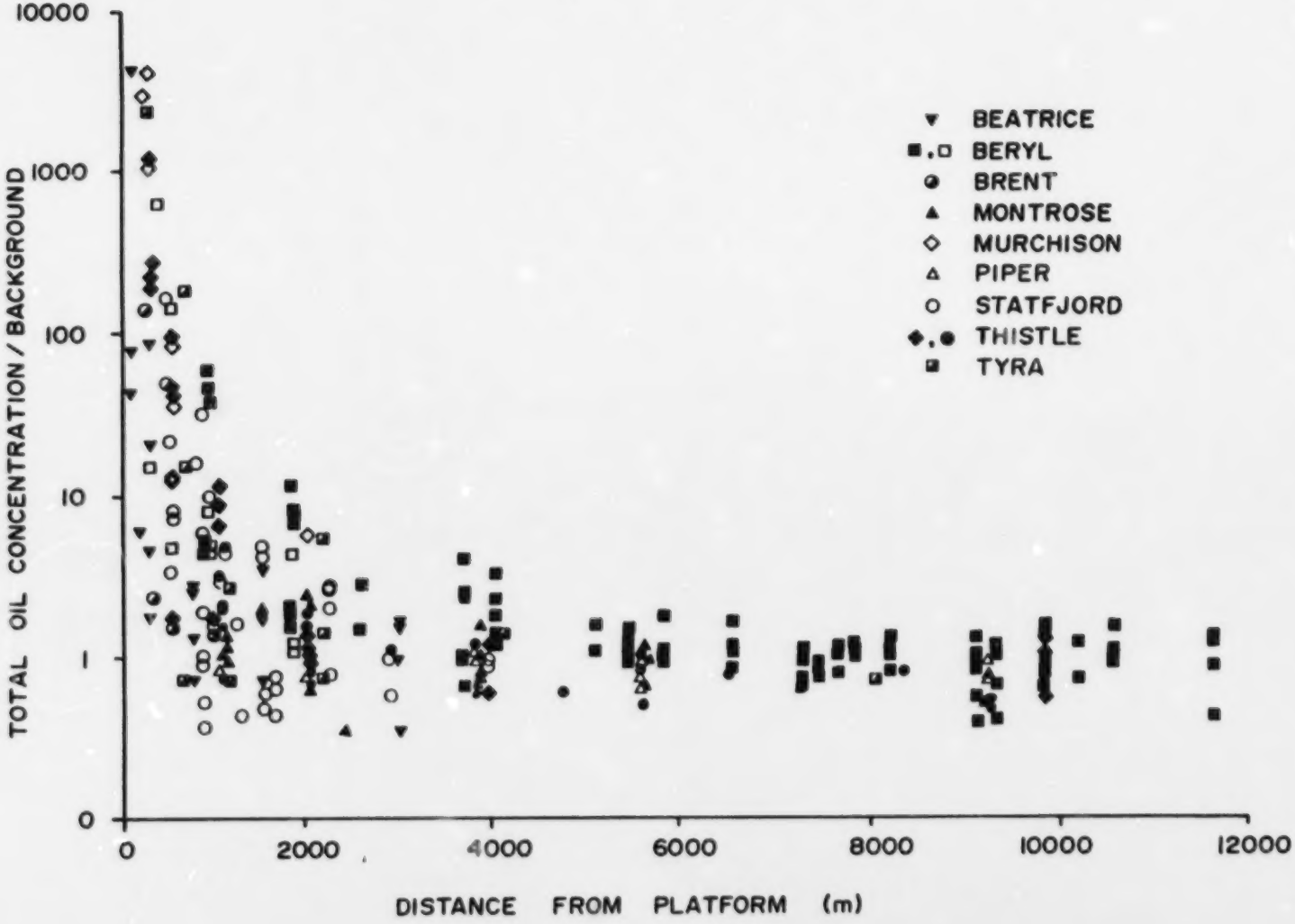
DIVERSITY VS CONCENTRATION



SPECIES DIVERSITY VS DISTANCE



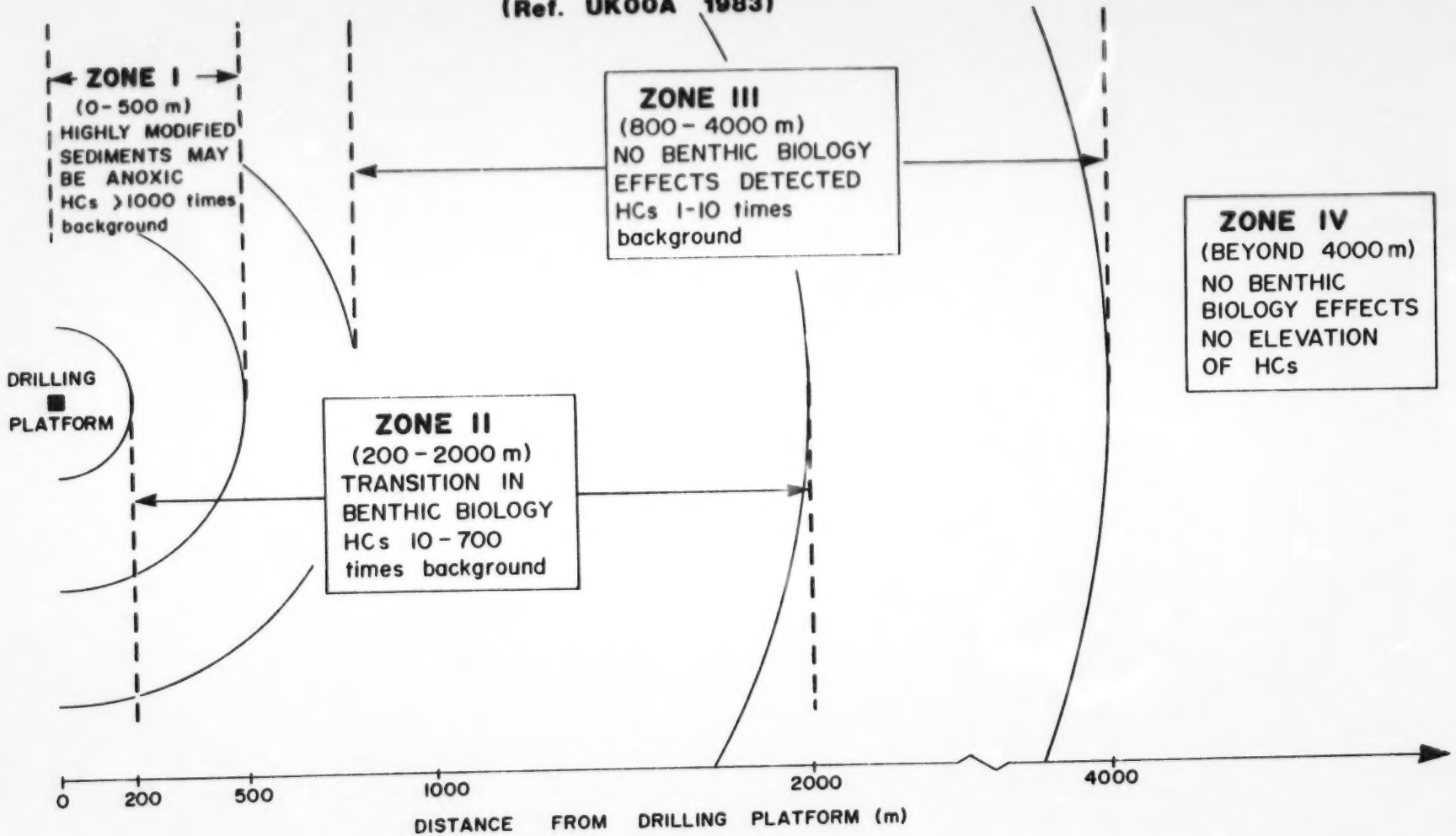
SPECIES (NO.) VS DISTANCE



$\frac{\text{TOTAL OIL}}{\text{BACKGROUND}}$ VS DISTANCE

ZONES OF EFFECT AROUND NORTH SEA PRODUCTION PLATFORMS

(Ref. UK00A 1983)



BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

Well Completion and Workover Fluids

- includes $ZnBr_2$, $CaBr_2$, $CaCl_2$, HCl, HF, surfactants, various viscosifiers
- effects limited
  - low use rate
  - dilution rapid
  - use intermittent

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

DRILLING WASTES

BOP Control Fluid

- primarily ethylene glycol
  - moderately toxic
  - readily degraded by seawater bacteria

Cement Slurry

- substrate loss and alteration
- mortality by smothering
- adverse effects expected to be very local and short-term because
  - only small quantities discharged
  - slurry hardens quickly

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

Ballast and Storage Displacement Water

- largest single source of transportation related petroleum to ocean
- dilution usually sufficient to render discharges harmless

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

Produced Sand

- volumes discharged usually low
- potential effects on infauna
  - local
  - probably indistinguishable from effects of cumulative oil discharge at production platforms

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

Sanitary and Domestic Wastes

- overall volume is usually small (approx. 10 - 15 $m^3 d^{-1}$ sewage and grey water combined)

- effects local only

BIOLOGICAL EFFECTS OF PRODUCTION WASTES

Oil and Gas Processing Wastes

- Wastes include:
  - oil wastes containing residual crude oil and small amounts of organic additives other than hydrocarbon compounds
  - toxic components
  - biocides
- Effects expected to be limited
  - amounts discharged will be small
  - receiving water dispersion usually large
  - toxicity of chemicals to marine organisms usually low

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

- Types of Zone of Influence
- Influencing Factors
- Dispersion Models
- Predicted Zone of Influence
- Environmental Significance

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

Types of Zone Influence

- Zone of Influence is a relative concept
- Delineation of the zone depends on several factors
  - choice of effects used to define the zone
    - physical disturbance
    - chemical disturbance
    - biological disturbance
  - sensitivity of the detection technique
  - fractionation of the discharge

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

Influencing Factors

- receiving environment concentrations affect ability to detect zone of influence
- depth of discharge
- discharge characteristics
- water phase oceanographic characteristics
- sediment dynamics

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

Dispersion Models

- object is quantitative prediction
- to date only drilling fluids and cuttings modelled in detail
- good input data essential
    - limited data base for Grand Banks, Scotian Shelf, Beaufort Sea
- verification difficult

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

Dispersion Models

- compromise approach
  - available input data
  - ease of computation (cost)
- simplifying assumptions
  - current field uniform
  - settling and rising at constant rate
  - material modelled is uniform
  - material modelled is conserved throughout dispersion process
  - material dispersed is passive in marine environment

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

Predicted Zones of Influence in Canadian Waters

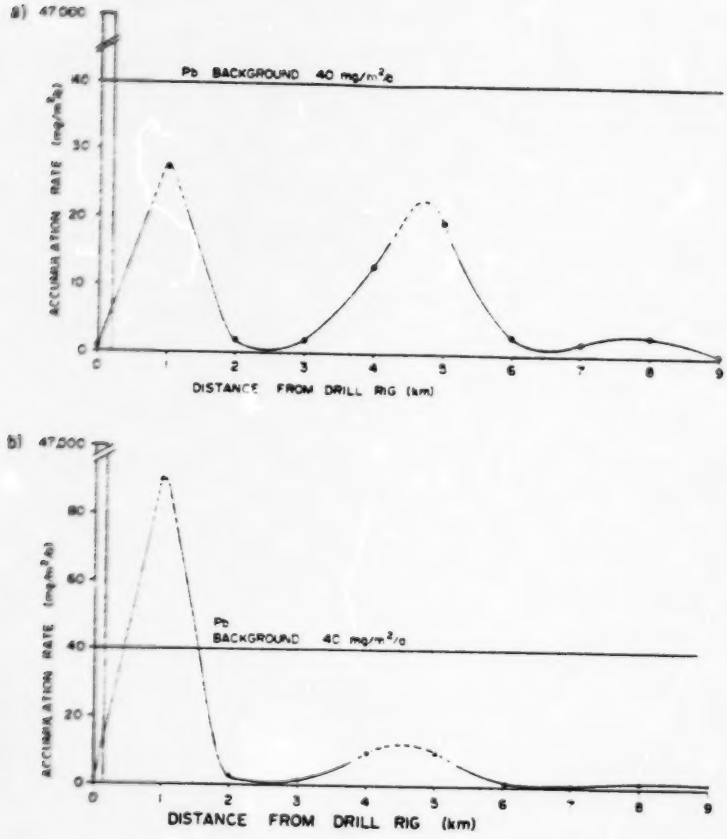
- Zone taken as zone around the point source discharge within which accumulation rate of a component "X" from industrial source exceeds 50% of the natural background accumulation rate for "X"
- Results - Scotian Shelf
  - Cd - approx. 8 km (surface discharge)
    - approx. 6 km (10 m discharge)
  - Cu - approx. 1.5 km (10 m discharge)
  - Pb - approx. 5 km (surface discharge)
    - approx. 1.8 km (10 m discharge)
  - Zn, Cr, Hg - < 200 m
  - hydrocarbons
    - approx. 6 km (surface discharge)
    - approx. 5 km (10 m discharge)
- Results - Grand Banks
  - all zones confined to 200 m around discharge

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

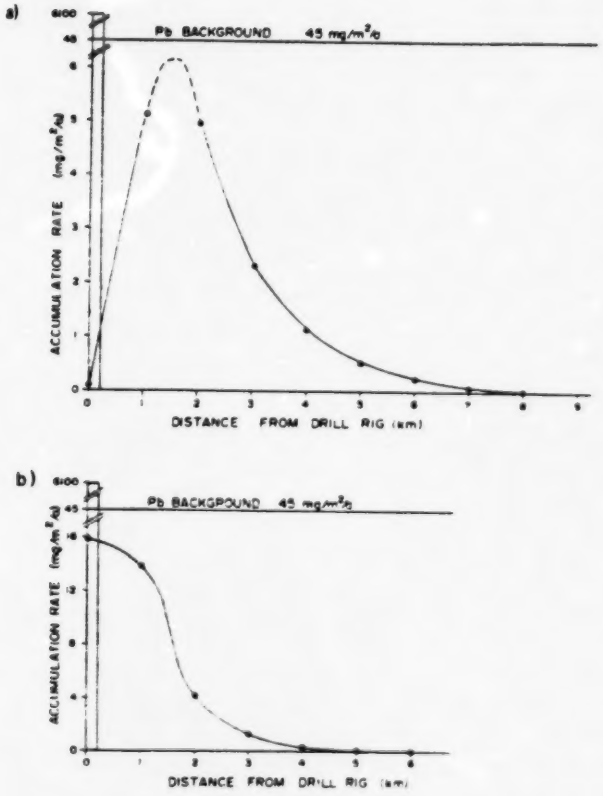
Predicted Zones of Influence in Canadian Waters

- Results - Beaufort Sea
  - metals - all zones confined to 200 m around discharge
  - hydrocarbons
    - approx. 2.5 km (surface discharge)
    - approx. 1.5 km (10 m discharge)

- Results
  - consistent with reported field measurements



ACCUMULATION OF DISPERSED LEAD IN SCOTIAN SHELF SEDIMENTS



ACCUMULATION OF DISPERSED LEAD IN BEAUFORT SEA SEDIMENTS

ZONES OF INFLUENCE AROUND OFFSHORE PLATFORMS

Environmental Significance

- Mass-balance approach
- Mass loadings (metals, hydrocarbons)
- Oil loadings: A comparison of offshore production and shipping sources (East Coast)
- Sewage loading

ENVIRONMENTAL OIL LOADINGS

	SCOTIAN SHELF (L/year)	GRAND BANKS (L/year)	SHIPPING (L/year)
	GAS FIELD	OIL FIELD	
Oil associated with produced water	3,000	292,000	
Oil associated with drill cuttings			
(a) for Water-base Muds	100,000	53,500	
(b) for Oil-base Muds	2,000,000	1,070,000	
Oil associated with ship bilge pumping			920,895
Oil associated with ship tank cleaning			1,625,345
TOTALS			
Water-Base Muds	103,000	345,500	
Oil-Base Muds	2,003,000	1,362,000	
Shipping Losses			2,546,240

BIOLOGICAL CONCERNS FOR CANADIAN OFFSHORE REGIONS

- Production Wastes of No Significant Biological Concern
- Concerns: Scotian Shelf
- Concerns: Grand Banks
- Concerns: Beaufort Sea

BIOLOGICAL CONCERNS FOR CANADIAN OFFSHORE REGIONS

Production Wastes of No Significant Biological Concern

- cuttings from water-base mud drilling operations
- well completion and workover fluids
- BOP control fluid
- cement slurry
- produced sand
- treated sewage and domestic waste
- gas and oil processing wastes
- ballast water
- storage displacement water

BIOLOGICAL CONCERNS FOR CANADIAN OFFSHORE REGIONS

Scotian Shelf

- drilling fluids/oil contaminated cuttings
  - hydrocarbon loading
  - trace metal loading

BIOLOGICAL CONCERNS FOR CANADIAN OFFSHORE REGIONS

Grand Banks

- produced water
    - chronic oil discharge
- oil contaminated cuttings
    - diesel oil
    - paraffin oil
    - formation crude

BIOLOGICAL CONCERNS FOR CANADIAN OFFSHORE REGIONS

Beaufort Sea

- produced water
    - chronic oil discharge
- oil contaminated cuttings
- long-term trace metal loading